Late Triassic and Early Jurassic Radiolarians from Timor, eastern Indonesia.

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Abstract

Rich fossil assemblages are used in a biostratigraphic and taxonomic study of the radiolarians occurring in the Aitutu and Wai Luli Formations of West Timor, Indonesia. The emphasis of this study is upon the abundant and diverse Late Triassic age radiolarians recovered from the River Meto sections of central West Timor and their comparison with other taxa found in Tethyan areas. The lower Mesozoic sediments of Timor form part of a displaced Gondwanan terrane and the Upper Triassic (Carnian, Norian and Rhaetian) taxa which are present in the Aitutu Formation compare closely with radiolarians reported from North America, Europe, Japan, China and the Philippines. Early Jurassic (Sinemurian, Pliensbachian and Toarcian) assemblages were also encountered, recorded and compared to those found in other regions. Sequences of co-occurringmicrofossils (including conodonts, foraminifera, ostracods and calcareous nannofossils) offer a control in confirming the age of the radiolarian assemblages encountered during this study.

One new genus (*Pseudolivarella*) and fifteen new Upper Triassic species (*Capnuchosphaera kapanesis, C. metoensis, C. timorensis, Deflandrecyrtium rhaetica, D. kozuri, Kahlerosphaera petalouda, Orbiculiforma kyklica, Palaeosaturnalis ovalis, Paronaella leebyi, Pentactinocarpus longispinosis, Pseudoheliodiscus carteri, Stauracanthocircus tozeri, Squinabolella? maxima, Pseudolivarella barkhami*) are described and their biostratigraphic significance discussed.

Informally, three assemblages and two subassemblages are recognised in the radiolarian faunas from Timor and these are as follows:

1) *Capnodoce-Capnuchosphaera* Assemblage (upper Carnian to lower Norian).
2) *Palaeosaturnalis* Assemblage (middle Norian).
3) *Kozurastrum-Citraduma* Assemblage (? upper Norian-Rhaetian) with two subassemblages.
3a) *Deflandrecyrtium-Livarella* Subassemblage (upper Norian) = *Betraccium deweveri* Zone
3b) ?*Parahsuum* sp. A-*Pseudolivarella* n. gen. Subassemblage (? upper Norian-Rhaetian).

The associations of taxa are defined using the abundant and highly diverse radiolarians from samples provided by Dr. S. T. Barkham. These were then tested on the less

abundant and diverse assemblages collected by the author and proved to be of use for age correlation. Assemblages from Indonesia were found to have more species also occurring in European Tethys, North America and the Philippines than elsewhere. This may be the result of patchy sampling/preservation in some regions or genuine palaeobiogeographical differences in faunal assemblages. The other studies which contain highly diverse and abundant assemblages have more species which also occur in Timor than reported assemblages containing low abundances and diversities of radiolarians.

The Lower Jurassic (Wai Luli Formation) contains less well-preserved radiolarians of Sinemurian-Toarcian age faunas and is briefly examined. These assemblages contain examples of the genus *Parahsuum* Yao, 1982 which occur frequently in the Lower Jurassic of Japan and are thus compared to taxa found in that region.

Chapter 1

Introduction

1.1.0 Introduction

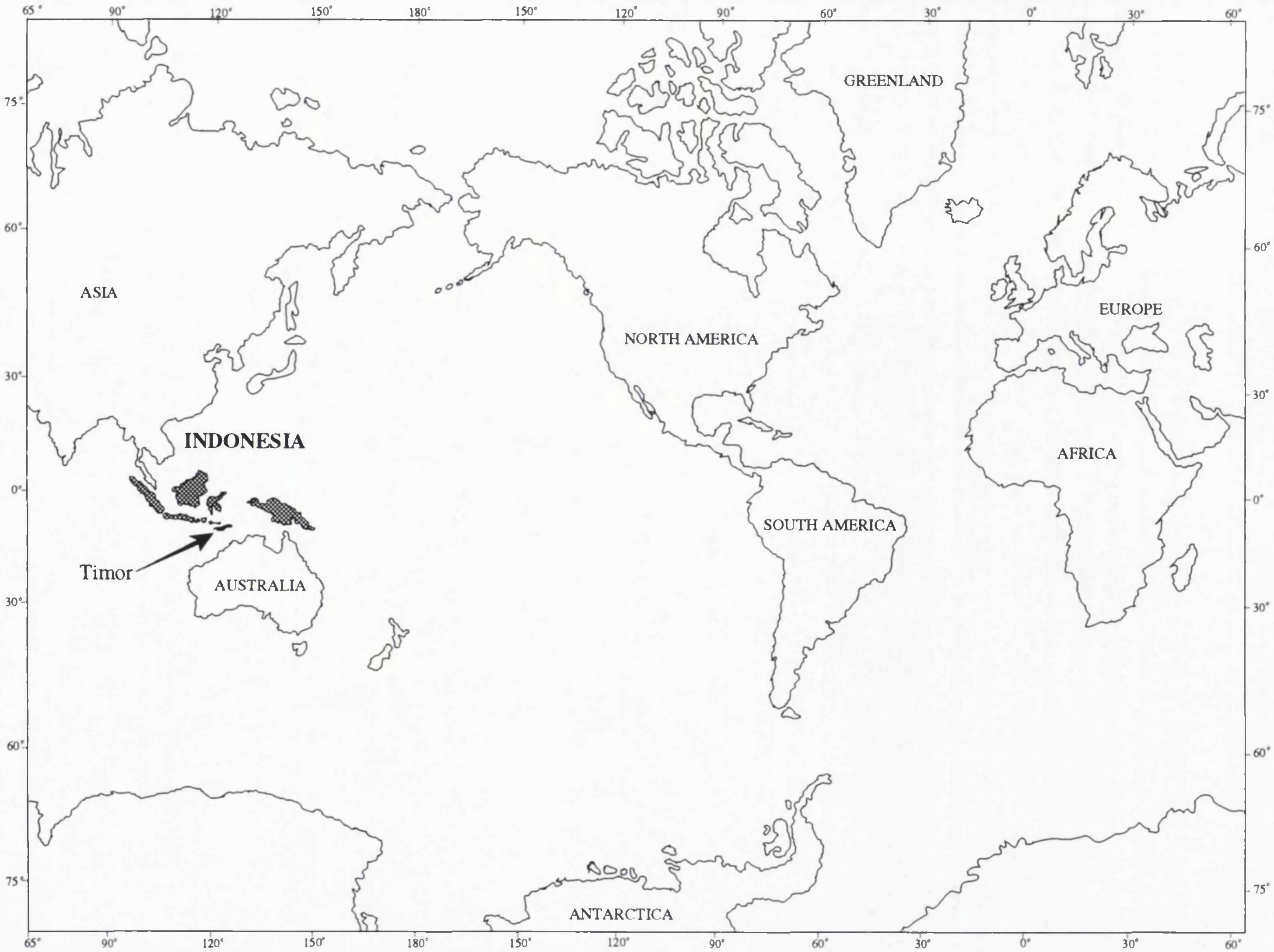
The aim of this project is to study the Late Triassic and Early Jurassic age radiolarian assemblages known to be present in abundance in the Mesozoic sediments of Timor, and other islands in the Banda Arc (Textfig. 1.1), and to compare the assemblage compositions with those of other parts of Tethys and non-Tethyan areas. During the first field season (1990) the majority of the sampling was carried out on Timor, however, the island of Buton was also visited as part of a separate project to assess the Mesozoic microfossil stratigraphy of the sediments found there. The study conducted on Buton also afforded the opportunity to collect samples to study radiolarian faunas reported by Smith (1985). In 1991 a second field season to the islands to the east of Timor was carried out in order to extend the sampling area

Some fossil groups such as found on Timor are said to be Austral in their affinity, and to have characteristics in common with examples recovered from the Australian area alone, and so are used to support the theory that Palaeozoic and Mesozoic continental fragments seen in islands of the Outer Banda Arc are slivers of Australian continental margin. This study documents the rich Late Triassic and Early Jurassic radiolarian assemblages in terms of their taxonomy, biostratigraphy and integration with other fossil groups (such as nannofossils) to test their regional affinity.

This study was financed by the University of London Consortium for Geological Research in Southeast Asia. Fieldwork was carried out with the support of the Geological Research and Development Centre (G.R.D.C.), Bandung.

1.2.0 Colonial history of Timor

Timor is still divided into two provinces, West Timor and East Timor, which is a relic of the colonial history of the island. This colonial history was driven by the sandalwood (*Santalum album*) trade, which had been taking place with the Chinese at least since the twelfth century A.D.. The Portuguese were the first European power drawn to Timor in 1515 by the plentiful sandalwood. Eventually they built small settlements and claimed Timor as a colony. The Dutch, in 1749, drove the Portuguese and local sandalwood traders east forcing the 'White Portuguese' to establish their



Textfig. 1.1 Location of Timor, eastern Indonesia

capital in Dili, and colonised the southwest tip of the island. The nineteenth century was a period of drastic change in the area with the Portuguese selling their claims to Flores and some smaller islands in the east to the Dutch. This led to the border agreement of 1858 which created Portuguese East Timor and Dutch West Timor. After World War II Indonesia gained independence and so inherited West Timor along with all of the other former Dutch colonies. The Portuguese retained East Timor until a revolution in 1974 replaced the pro-colonial regime with a left-wing separatist one. In 1975, the Indonesian government, fearful of communist takeover in East Timor invaded and annexed the area.

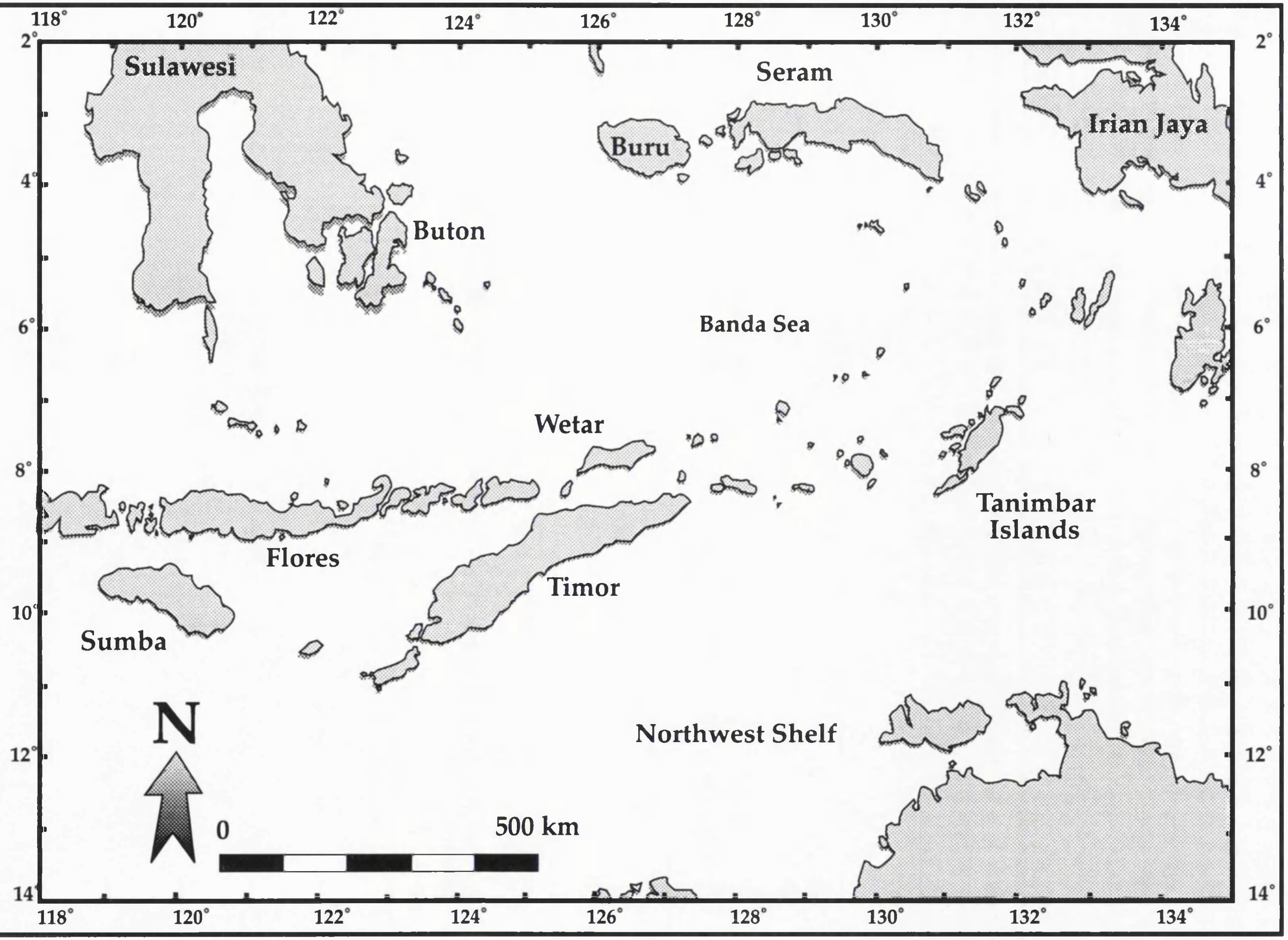
1.3.0 Location of field areas

Timor is situated in the eastern part of Indonesia (Textfig. 1.2) on the southern fringe of the Banda Arc and is the largest of the Lesser Sunda Islands. To the north lie the islands of Flores, Alor and Wetar, to the east the smaller islands of Leti, Moa and Babar, and to the south Australia separated by the 500km of the Timor Sea. The island of Timor itself is some 470km long from east to west and 105 km wide at its broadest point.

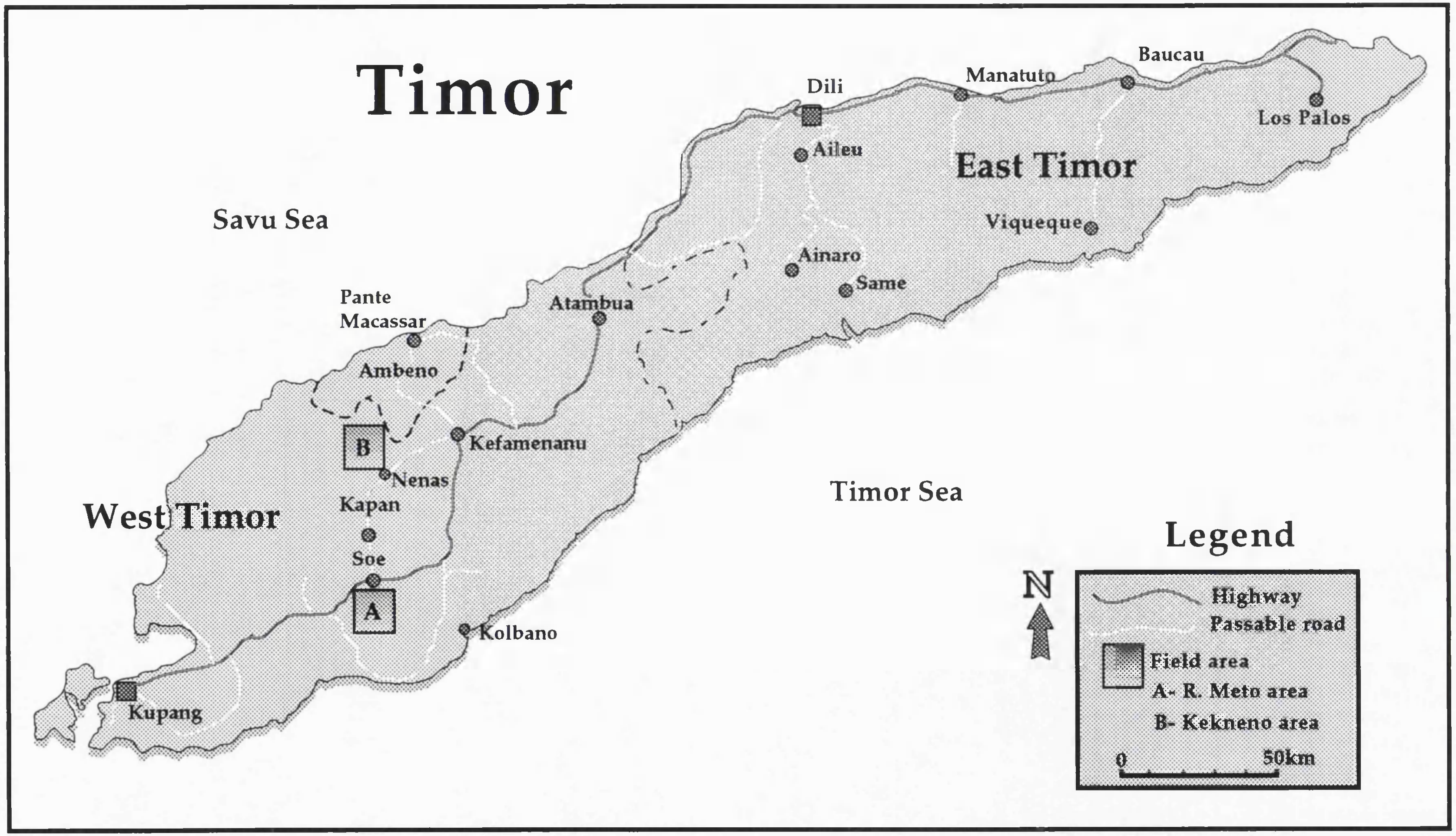
The field area for this study is in central West Timor, just south of the town of Soe (Textfig. 1.3), with a short period of time spent in the Kekneno area (Textfig. 1.3) which is situated in the hills approximately 40km to the north of Soe.

Buton is situated off the southern tip of the southeast arm of Sulawesi (Textfig. 1.2) and is approximately 200km through its longest axis from northeast to southwest and around 80km in width at its broadest point. This island is in the extreme northwest zone of the Banda Arc and is somewhat separated from the other islands in this system. Mesozoic sediments of Australian affinity are believed to form the oldest rocks seen here.

The second field season concentrated on the islands to the east of Timor (Leti, Moa and Babar) (Text-fig. 1.4) in order to extend the area of sample collection and to compare faunas recovered with those of Timor. These islands are believed to share a similar geological history to Timor and other islands in the Banda Arc in that they are thought to be slivers of Australian continent rifted away and later deformed and incorporated into the collision zone between the Australian and Asian plates.



Textfig. 1.2 Timor and other islands studied during this project



Textfig. 1.3 Location of field areas studied during this project

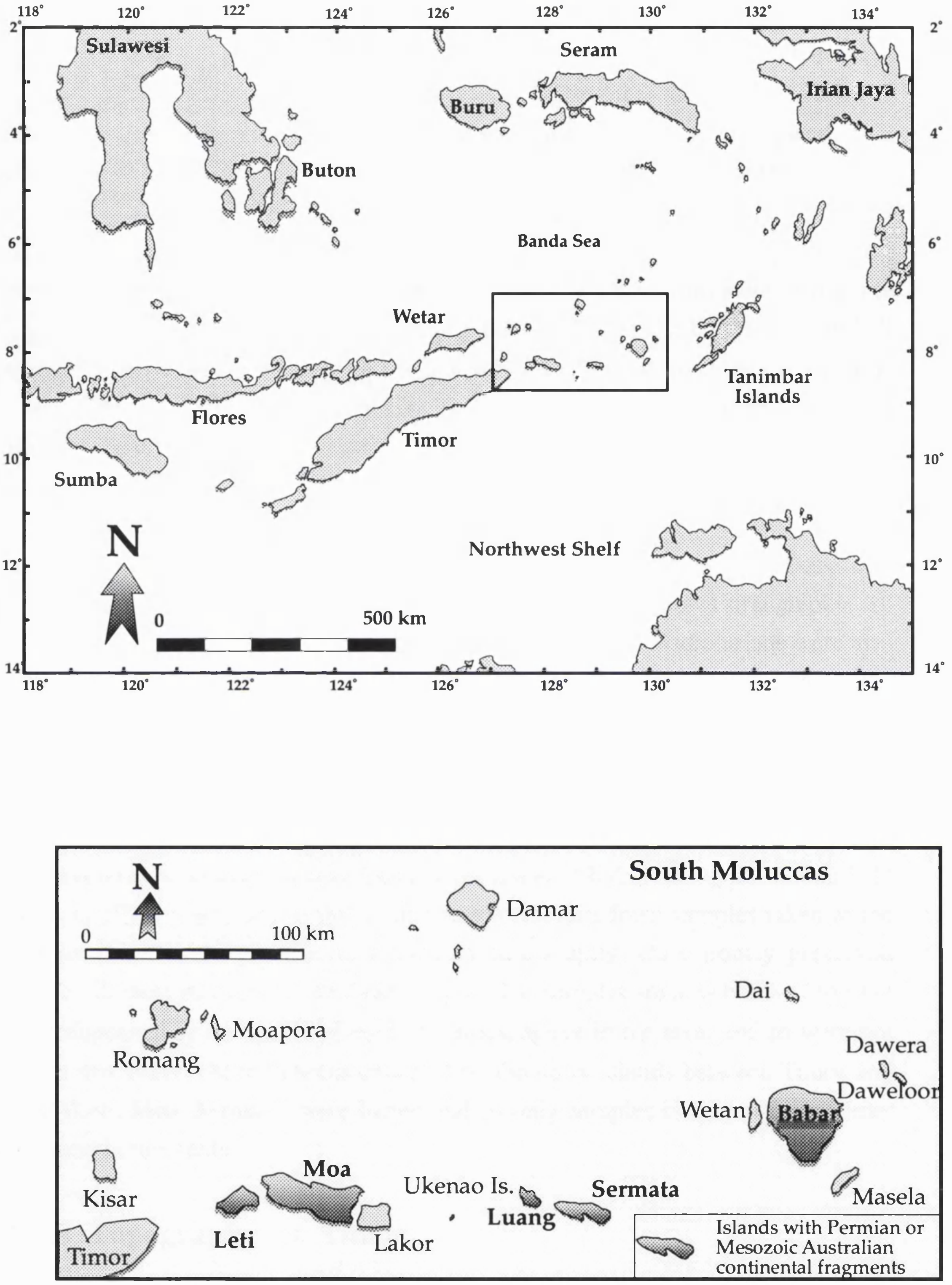
1.3.1 Access to the field areas

All geological fieldwork in Indonesia requires a visa from the Indonesian Embassy. For the 1990 field season a four week social/tourist visa was obtained in London which was later changed to a business visa in Bandung. Clearance for fieldwork was also required from the Ministry of the Interior and security police; visas were organised by G.R.D.C.. For the 1991 field season a business visa was acquired from the Indonesian Embassy in London and further permission was obtained from the Indonesian Science Foundation, L.I.P.I., in Jakarta as well as visa extensions in Bandung.

Travelling to the capital of West Timor, Kupang, from Jakarta or Bandung is relatively simple as several flights a day leave and head east usually to Surabaya then on to Bali. A regular service from Denpasar to Kupang via Flores or Sumba will take only a few hours. Once in Kupang, a visit to the Sospol, a local government official, at the governors office was necessary to obtain a letter of introduction for the Bupati (official) in Soe. The journey from Kupang to Soe was made by one of the regional buses which travel east to Atambua and Dili twice daily. All of the buses use the main road running through the centre of Timor and stop off at Soe. The losmen (small guest house) Bahagia was used as a base for the fieldwork as it was situated within one hours walk from the headwaters of the Noil Meto. This was the main area of fieldwork, however, a brief trip to the Kekneno region was made in order to compare lithologies and fossil content of the two sites which are believed to be age-equivalent. To reach Nenas, the village closest to the field area of previous studies by Cook (1986) and Bird (1987), a truck was hired to make the journey. Once north of the town of Kapan the road becomes a rough dirt track and from here to the destination the going is extremely slow.

Travelling to Buton consists of firstly a flight to Ujung Pandang via Surabaya. Once on Sulawesi a second flight to Kendari was undertaken where permission from the local security force was gained before the trip to Buton itself was made. A regular ferry service runs from Kendari via Raha on Muna, the neighbouring island, to Baubau (meaning smelly in Indonesian) the major town of Buton; this takes approximately 12 hours. On completion of official business, access to the field areas was made by the use of local transport (bemos-minibus).

The second field season to the islands to the east of Timor was very much more complex as the administrative centre for these islands (Maluku seletan) is Ambon. A



Textfig. 1.4 Location of the islands to the east of Timor visited in 1991

flight from Bandung to Ujung Pandang via Denpasar was taken. In total seven days were needed to obtain visa extensions in Ambon. During this time the possibility of chartering a boat across the Banda Sea to the south Moluccas was investigated. This proved prohibitively expensive, because in order to cross this open stretch of sea a large boat was needed. Oil company activity had also inflated the prices paid for chartered vessels. It was decided that the only way to reach the study area at a reasonable price was to travel to Dili, East Timor and hire a boat from there. A flight to Kupang via Ujung Pandang was taken and then one of the regular bus services to Dili through central Timor. The journey takes approximately 17 hours over the tarmac roads of West Timor and the dirt tracks of East Timor. One of the small (20m) cargo boats making regular trips to Kisar, a nearby island, was chartered for 28 days to visit the islands between Timor and Babar.

Fieldwork carried out on Buton was part of a separate project financed by Conoco to sample Mesozoic sediments and investigate the accuracy of the known stratigraphy. All microfossil groups were used as well as macrofossil evidence. Radiolarians were also recovered but were Cretaceous in age and so not used in the present study as it was thought that the age range (Late Triassic to Cretaceous) of the assemblages was too great to bring together in a cohesive piece of work. Faunas recovered from Buton were stored for a possible future project.

Excellent Jurassic ammonites were found on the island of Babar during the second field season in 1991. It was hoped that a suite of microfossils from samples taken at the same location would provide an integrated stratigraphy. Only poorly preserved microfossils were recovered from these samples. The samples are now believed to have been redeposited by the action of mud volcanoes, active in the area, and so were not used in this study. Other samples collected on the other islands between Timor and Babar (Leti, Moa, Sermata) were barren and so only samples collected from Timor were used in this study.

1.3.2 Topography of Timor

Timor is an island dominated by a core of rugged hills and mountains and is divided by a central basin. Coastal areas consist of raised reefs and alluvial deposits. Even in the central regions Coralline Limestone is found, an example of this is seen in the Soe area where Pleistocene uplifted reefal limestones cap the hills at a height of more than 900m above sea level. Most of West Timor consists of rugged hills with steep slopes. A combined daily descent and ascent of around 800m was undertaken to reach the mapping area during the course of the fieldwork for this study. The deeply incised topography is as a result of uplift (10cm/year in some places) following the collision of the Australian continental margin with the Asian plate in the Pleistocene.

1.3.4 Climate and vegetation

Timor has a transitional climate between the humidity of Indonesia and the dry heat of Central Australia. A wet season occurs from October to April, after which the dry season begins. A total of 1500mm of rain per year is the norm apart from the highest regions. This seasonal rainfall results in rivers rapidly swelling at the beginning of the wet season with frequent flooding which changes the outcrop pattern each year. During the dry season rivers in many areas such as that of the River Meto, just south of Soe, contain no water, whereas the rivers in the uplands such as those found in the Kekneno area may still be flowing even at the end of the dry season.

The proximity of Timor to Australia and its southerly position produces a different climate to the rest of Indonesia. In some hilly areas, Timor appears similar to the Australian outback with open eucalyptus forest, in other places savannah predominates. The savannah vegetation is a direct result of the overcutting of sandalwood and other trees for the timber trade and of farming methods used by the inhabitants. In the highlands, where the population is smaller, primary forest still survives and where the dry season is short at a height of 1000m or more above sea level upper montane rainforest is seen (Cook, 1986).

1.3.5 Exposure

In general, exposure on Timor is much better than in many places in Indonesia, where wetter climates sustain rainforest vegetation and where any new outcrops are rapidly weathered and buried under deep tropical soils. On Timor the open vegetation and deeply incised rivers produce large and clean outcrops free from the problems encountered in primary rainforest, etc.. Some outcrops occur along pathways, however, the vast majority of mapping and sample collecting was done in dry river beds.

1.3.6 History of exploration in West Timor

Reports of the presence of copper ores were the trigger for the first geological expeditions to be made to West Timor. The Dutch colonial government sponsored three geological expeditions which carried out a great deal of useful work. Jonker led the first expedition in 1872. It was not until 1919 that the next expedition was undertaken by van Es and this continued until 1923. Macklot in 1929 led the third, which resulted in the preparation of the first geological map of the area. Wanner made an excursion to the island in 1909 and discovered rich Palaeozoic and Mesozoic fossil faunas which led to further expeditions (1910-11). Molengraaff (1912-15) was one of the first to recognise the similarities between the structures encountered on Timor and those of the Alpine region. More detailed investigations were carried out by Brouwer in 1937. He and his team of students published four volumes (Brouwer, 1940-42) on the geology of the province.

Following independence various expeditions were financed by the Indonesian government which have culminated in the publication of a geological map (Rosidi *et al.*, 1979). Since the 1950's a steady stream of geologists from all over the world have visited East and West Timor in an attempt to solve the complex geological problems of the island. Recently, Barkham (1993) and Kristan Tollmann (1988) have worked on the Triassic and Jurassic sediments found along the River Meto. Timor and the islands of the Banda Arc are also important in that they represent mountain building in its earliest stages and the area is critical to the tectonic and structural understanding of these processes.

1.4.0 Methods of fieldwork

Initially topographic base maps made by the Dutch between 1923 and 1938 were used for approximate positioning. These show the main settlements, rivers and roads, however, the contours are not accurate and so are of little use when mapping. Other maps are not of a suitable scale for use in detailed mapping. Fortunately, many of the sections visited during the course of this study were mapped and sampled by Barkham (1993) as part of his study of the sedimentology and structure of the Permian and Triassic of West Timor and so his location maps were utilised. New maps were also made using the step and compass method.

Sampling carried out for micropalaeontological analysis by many non-palaeontologists often proves unsuitable for either processing or for potential fossil content. In order to have enough material for splits and several processing runs, using different techniques where necessary, samples have to be approximately 250 cm^3 or more (about the size of half a housebrick). Suitable lithologies are also important when collecting for micropalaeontological analysis. The softer calcareous lithologies such as marls, calcareous mudstone and shales are most suitable for fossil extraction, as they require minimal processing with little or no reagents. Crystalline limestones are more difficult to process and may sometimes yield only thin section data. As far as radiolarians are concerned, limestones, marls and shales offer the best opportunity for recovery. Cherts are also desirable for the extraction of radiolarians, although processing is time-consuming and uses dangerous reagents such as hydrofluoric acid. During the course of the fieldwork for this study soft, calcareous lithologies were taken in preference to more indurated rock types.

Sample spacing is also critical in terms of biostratigraphic resolution. To achieve good coverage sample spacing must be close. Occasionally spot sampling was the only method available as outcrops tended to be small and infrequent. Where sections were large enough, samples were taken at 50-100cm intervals, or closer if suitable lithologies were available. All samples were bagged, labelled and replaced on the section from where they were taken and then photographed to show their relative position. Each sample location was then mapped and logged with relative sample positions plotted from the base to the tops of each log. At a later stage, all logs and hand-drawn location maps were re-draughted on computer.

1.5.0 Radiolarians: definition and uses

1.5.1 Introduction

Radiolarians are holoplanktonic protozoa widely distributed in the oceans, including arctic, subtropical and tropical waters, occurring throughout the water column from near surface to hundreds of metres depth (Anderson, 1983). These organisms are generally nonmotile with adaption for bouyancy. Radiolarians produce a skeleton consisting of amorphous silica and it is this skeleton which is studied by palaeontologists.

1.5.2 Classification

The seemingly endless variations and combinations of solid geometric designs, bears witness to the adaptive plasticity and sophisticated phylogenetic development of this group of organisms (Anderson, 1983). The basis for the classification of radiolaria is not universally accepted by researchers, however, for many it is the pseudopodial network which is used to assign the group to either the Sarcodina or Actinopoda. The modern classification of radiolaria places the group in the Kingdom Protista, Phylum Sarcomastigophora, Subphylum Sarcodina, Superclass Actinopoda with radiolaria being divided into Polycystina (studied in this project) and Phaeodarea (rarely found fossil).

Polycystine radiolarians are usually divided into two suborders the Spumellaria and Nassellaria, based on their symmetry. Spumellaria are considered to be the most primitive group and are based on radial symmetry and may be divided into the following three basic types: 1) spicular forms i.e. simple needles to complexly arranged triradiate spines, 2) more elaborate skeletons composed of spheroidal to spherical shells, and 3) complex polyhedral shells resembling lattices. Spumellarian radiolarians may be solitary or colonial with filiform species forming colonies up to several metres in diameter. Nassellaria have a lateral symmetry and are usually cone or egg-shaped consisting of a single pore field (porochora) at one pole of the central capsule. As with the Spumellaria, the Nassellaria consist of three fundamental types: 1) skeletons consisting of a tripod located near the base of the central capsule, 2) forms consisting of a conical or helmet-shaped, perforated shell, and 3) a sagittal ring that reinforces the latticed shell in the medial sagittal plane.

1.5.3 Palaeoecology and evolution

Fossil radiolaria are significant sources of information in the earth sciences for micropalaeontology, stratigraphy, palaeoecology and other disciplines (Anderson, 1983). Radiolarian palaeoecological research is often aided by excellent fossil assemblages recovered from many studies and this has led to the publication of a large body of literature dealing with skeletal morphology. Much of the information recovered from the fossil record is inferred, however, it is still possible to reconstruct to some aspects of the ecology of fossil assemblages (such as temperature, nutrient availability, etc.).

Radiolarians appear to have evolved during late Precambrian or early Palaeozoic time and have generally (except in the Permo-Triassic) increased in diversity through geological time to the present day and have the longest record by far of marine plankton of known biological affinity (Textfig. 1.5). This group has one of the most complete geological records throughout Phanerozoic time despite problems of preservation. Evolutionary studies lack data from the soft parts of most fossil groups and this is the case with radiolarians, therefore only the hard skeletal fragments may be used to interpret phylogenetic history. Assumptions may be made about the soft parts of these organisms from the morphology of the hard parts.

Radiolarians recovered during this study are in general well-preserved, abundant and diverse and are used for taxonomic and biostratigraphic purposes. Assemblages from Timor consist of distinctive Carnian, Norian and Rhaetian faunas (Late Triassic age) as well as Sinemurian to Toarcian (Early Jurassic age) taxa.

1.5.4 Project Aims

The aims of this project are as follows:

1) Report the fossil radiolarian content of the Aitutu and Wai Luli formations in Timor.
2) Accurately define the age of the Aitutu and Wai Luli formations.
3) Compare the radiolarian age data to that of co-occurring fossil groups (conodonts, calcareous nannofossils, foraminifera, ostracoda, ammonoids and bivalves).
4) If possible, erect a biostratigraphic zonation scheme for the Upper Triassic using radiolarians.
5) Compare radiolarians assemblages from Timor to those found in other regions.

Chapter 2

Preparation and illustration techniques

2.0.1 Introduction

Preparation methods have as their goal the removal of unwanted material (matrix) leaving a complete and undamaged fossil assemblage. Good illustrations are the key for a complete and thorough description of most biological and fossil species and this is especially valid for organisms such as radiolarians (Boltovoskoy *et al.*, 1983). It is to this end that preparation and illustration techniques are so vital, as microfossil groups including radiolaria have their taxonomy based on morphology. Furthermore, some extraction techniques may seriously alter the assemblage composition of samples and therefore distort placing within zonation schemes, and so careful attention must be paid to this subject in order to extract fossil assemblages that are as close as possible to the original fauna. Physical, chemical or a mixture of the two methods may be employed to attain the end result.

Hand drawings, as used by workers prior to the introduction of modern photographic methods, were and still are a powerful tool, however, the comparison of images can, in general be most objectively carried out using photography. Haeckel (1881) produced idealised hand drawings of his specimens, while Petrushevskaya (1967, 1971) and Dumitrica (1978, 1982) have attained more realistic drawings. Many authors (Baumgartner, 1980, De Wever, 1982) still use drawing to clarify taxonomic detail when photography cannot do this.

Most work in recent studies of radiolarians (from the early 1970's onwards) has involved identification and photography of skeletons in transmitted light. Specimens are cleaned and mounted in Canada balsam, Caedax, Hydrax, and recently in Norland Optical Adhesive. This method allows reliable comparison between specimens observed and those seen in the literature, and also enables internal structures to be observed, such as internal shells, beams and canals. Problems may, however, be encountered if the refractive index of the mounting medium and the specimen are similar. To counteract this, a mounting medium with a large difference in refractive index to the material under investigation is required.

New methods of extracting radiolarians from various sediment types such as cherts (Pessagno and Newport, 1972) increased their availability for use, especially in biostratigraphy. A number of preparation techniques for many of the rock types which contain radiolarians have been developed and published (Ashby, 1983, Boltovskoy *et al.*, 1983, etc.).

The widespread use of SEM photography since the mid 1970's has greatly improved and expanded the taxonomy of this group of fossils. Some disadvantages occur with the use of SEM photography and these include: 1) inability to observe internal structure (unless specimens are broken, which may in fact, offer the best way to observe internal structure), 2) difficulty of comparison with light microscope images, 3) generally slow work rate (mounting and photography), and 4) expense of equipment, which may not be available to all workers. Despite these problems SEM photography is now very widely used and is the norm in published literature.

2.2.0 Preparation techniques

2.2.1 Introduction

Living polycystine radiolarians have tests composed of opaline silica. During fossilisation this material is unstable and is replaced by calcite, pyrite, or undergoes a phase change from opal, CT, and quartz. The sediment type of samples to some degree determines mineral replacing the original material. In this study radiolarians were preserved as calcite and silica and were recovered from limestones, cherts, marls, shales and mudstones, and therefore a number of extraction techniques were used and refined.

2.3.0 Extraction from chert and silicified lithologies

Dumitrica (1972)

The technique of Pessagno and Newport (1972) was used and refined (by differing acid strengths and times of immersion) on several chert samples. A series of preparation runs were made on each sample using different acid strengths and immersion times. The technique of Pessagno and Newport (1972) using hydrofluoric acid is based on the differences in stability of the silica of the radiolarian test and that of the surrounding matrix which allow differential acid etching.

A basic prerequisite for the success of the method is that a chert must contain abundant, well-preserved radiolarians that are not badly recrystallised (Pessagno and Newport 1972). The technique used in this study assumes that a large amount of sample is available (approximately 250 cc) and is based on the method of Pessagno and Newport (1972) with a few additions and is as follows:

1) A fragment of chert is etched with concentrated hydrofluoric acid (40%) for three to five minutes, removed from the acid then washed in water. If well-preserved radiolaria are observed standing out form the surface of the chert fragment then the extraction technique may be continued, however, if only poorly preserved or no radiolarians are seen then it probably is not worth continuing with that particular sample.

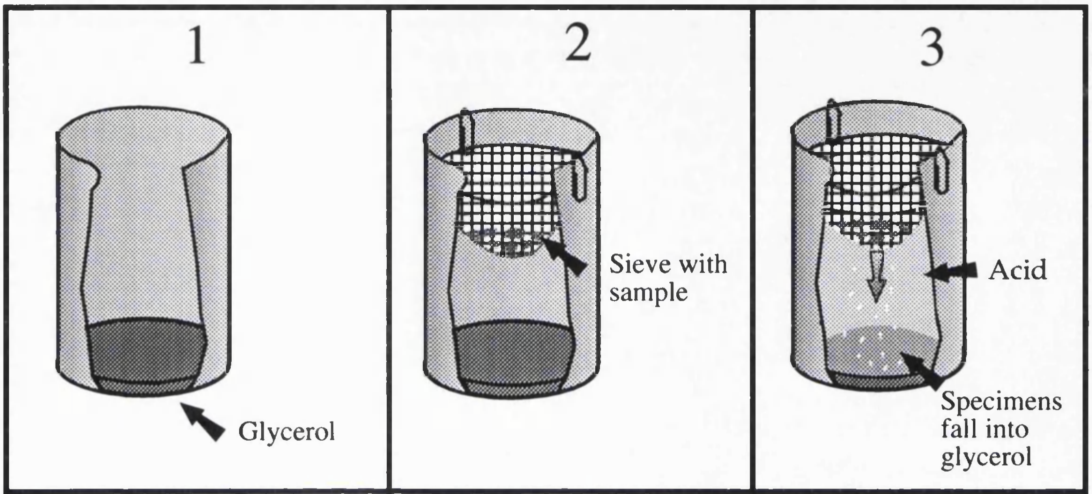
2) The sample is then crushed into fragments of less than a cubic centimetre (Pessagno and Newport, 1972, advise 1-5cm fragment) to introduce a large surface area to the acid.

3) The crushed sample is then placed in a cupped plastic mesh with holes of 1mm in diameter. The mesh containing the sample is then pinned inside a plastic beaker (Text-fig. 2.1) containing a few millimetres of glycerol at the bottom, which protects any specimens which fall through the mesh from further dissolution. The mesh, which is held in place above the glycerol, is fixed to the beaker with several paper clips. Dilute hydrofluoric acid is the poured into the container to just submerge the entire sample. Acid strength is varied between 2 and 6% in up to three splits of the sample in order to obtain the optimum strength, which is then used in another run on the same sample.

4) Each sample is then removed from the acid after six to eight hours and washed in warm water (to dissolve the glycerol) over a nylon sieve stretched on PVC frame (standard palynological sieve equipment with holes 10μm in diameter and then dried in a warm oven. The sample may then be examined using a reflecting light microscope and assessed for reprocessing. If the radiolarians need more cleaning then repeat parts 3 and 4 of the technique.

2.3.1 Discussion

A wide variation in results was commonly encountered when using hydrofluoric acid to extract radiolarians from cherts. Only a few chert samples were recovered for



1) Pour a few mm's of glycerol into the bottom of a standard plastic beaker.	2) Pin the plastic sieve (mesh 1mm) into the top of the beaker with paper clips and place the sample in the mesh.	3) Add the acid to the beaker so that it just covers the sample in the sieve and leave for the required time.

Textfig. 2.1 Sample preparation technique for limestone and for chert (suitable for hydrofluoric and other acids)

examination in this study and large-scale experimentation with extraction techniques could not be carried out. Many of the samples collected proved unsuitable in terms of their fossil content and parts 2-4 of the above preparation method were not followed. More suitable samples produced only modest assemblages and this may have been as a result of relatively poor faunas preserved within the cherts and silicified limestones, the type of chert encountered (general sugary texture as opposed to the smooth fine-grained examples from other areas) or a failure in the extraction technique. Other workers have had great success with chert lithologies (Pessagno and Newport 1972, Nakaseko and Nishimura, 1979; Yao, 1982; Kojima and Mizutani, 1987; Hori, 1990) and this is especially true of Japanese palaeontologists, who work almost exclusively with cherts and silicified lithologies. Variation of the hydrofluoric acid strength may also produce better results, but is generally time-consuming; an example of this is to place a sample in 0.5% HF and to check its effect at 30 minute intervals (this method is used by some European workers).

2.4.0 Extraction from shales and mudstones

Standard micropalaeontological techniques were used with this group of lithologies, however, a certain amount of experimentation was made. Several different methods may be employed depending on the induration, mineral content and lamination of the sample.

2.4.1 Hydrogen peroxide (H_2O_2)

Two different methods were utilised when disaggregating shales or mudstones with hydrogen peroxide. The first technique involves drying the sample, placing it in a bowl then immersing it in 20% H_2O_2 for several hours. Samples using either method were then washed over a 63µm sieve and dried in a warm oven. If pyrite is present then H_2O_2 treatment would produce sulphuric acid fumes. No remedial treatment was carried out during processing as pyritised radiolarians were not present in these samples before treatment.

The first method described was found to be highly effective in disaggregating shales and poorly indurated mudstones, completely reducing the sample to a sludge within minutes. This allowed quick and simple washing over a sieve (63µm mesh) two or three times, with drying in-between, which helps to remove the matrix and totally clean detritus from around the skeletons. The second method was used on the more indurated samples. Boiling increased the vigour of the process and resulted in disaggregation, although it was necessary to dry some samples and repeat the process (with H_20_2).

2.4.2 Sodium carbonate (Na_2CO_3)

This technique was only used when samples were soft (mudstones and marls) and fissile, and could be broken by hand because this technique is gentle and does not greatly damage tests. Again, each sample was dried in a warm oven for several hours, then placed in a bowl, immersed in Na_2CO_3 and water and heated for one to two hours. The sodium carbonate helps in the disaggregation process by dispersing the clay minerals. Samples were then cooled and washed over a 63µm sieve and then dried in a warm oven. On most occasions this process had to be repeated several times before the radiolarian skeletons were completely clean.

Overall, although occasionally time-consuming, this method produced excellent results in terms of well-preserved, assemblages with an high proportion of unbroken specimens. Relative simplicity, low-cost and high effectiveness make this technique advisable when suitable lithologies are encountered. The well-preserved nature of the fossils is a result of encapsulation within marls or mudstones, and not the extraction technique which only ensures relatively damages-free removal from the sediment.

2.4.3 Hydrochloric acid (HCl)

Calcareous mudstones were chosen for immersion in hydrochloric acid, because the action of dissolving calcareous cements by the acid was the only technique suitable for the relatively damage-free extraction of radiolarian tests. This method allows the removal of calcareous microfossils, which may mask the radiolarian content of the sample. Calcareous microfossils are, however, generally useful as they can be used to integrate zonal schemes based on forams and nannofossils with those of radiolarians. A split of each sample undergoing immersion in HCl was taken and processed using other techniques in order to retrieve the calcareous microfossil content.

Each sample was dried, crushed and placed in a beaker to which was added 5-10%

HCl. The relatively dilute nature of the acid used was to prevent a violent reaction which could result in the loss or contamination of material. After several hours of digestion samples were washed over a sieve (63µm mesh), dried and checked to assess $CaCO_3$ content, then reprocessed an appropriate number of times to gain a clean sample.

This extraction method is relatively inexpensive and safe as only weak solutions of acid are used. The main disadvantage is the time needed to process large numbers of samples.

2.4.4 Discussion

In order to determine the most suitable processing technique each sample needs to be assessed individually for lithological type and chemical composition, fissility, induration and type of cement. Generally, the softer lithologies yielded the best preserved faunas, which is likely to be a result of primary preservation within these lithologies combined with the ease of extraction of the fossils.

2.5.0 Extraction from limestones

Almost 90% of the samples studied in this project were limestones, therefore, processing this lithological type constituted the bulk of the lab work. In the published literature limestones are in fact the most common lithology from which radiolarians are recovered (Carter, 1988, 1990; De Wever *et al.*, 1979, 1981, 1982; Kozur and Mostler, 1990, etc.). This is perhaps a result of collecting bias by workers who realise that limestones often contain very well-preserved radiolarian assemblages, which may easily be extracted. Indeed, Blome while studying various Mesozoic formations in Oregon, Alaska and the Queen Charlotte Islands, Pessagno studying the Queen Charlotte Islands, Oregon and California, and Carter studying the Queen Charlotte Islands looked for and collected from carbonate concretions and nodules (concretions and nodules may preserve the fullest assemblages, closest to the original biocoenosis, or the only assemblages in some lithologies). Early diagenesis in and around these concretions appears to have enhanced the preservation of radiolarians. Doggers were reported in the River Meto sections by Barkham (1993), however, none were found during the fieldwork for the present study.

2.5.1 Acetic acid (CH_3COOH)

The technique of using gentle dissolution with acetic acid was carried out on all limestone samples collected by Barkham during the course of his field work. Dissolution of $CaCO_3$ using this acid was undertaken by him to recover conodonts, and was found to yield well-preserved radiolarians.

Crushed limestone was placed in a plastic beaker to which was added a solution of 15% acetic acid. The contents of the beaker were then left overnight. Samples were then washed over a 63µm sieve, dried in a warm oven, then examined using a reflective light microscope, and if necessary reprocessed using the same technique.

The Lower Jurassic limestones collected from the River Meto sections contained radiolarians with skeletons replaced by calcite and had to be processed in a manner so as not to dissolve the specimens. The method of Pessagno (1977) of first replacing the calcite of the skeletons with fluorite by soaking the sediment in hydrofluoric acid, and suspending sediment in a mesh and floating HCl on (glycerol in this study) chloroform thus allowing specimens to fall away from the acid was employed. Samples were crushed and placed in a coarse sieve (1mm mesh). This was then pinned into a plastic beaker with a few millimetres of glycerol in the bottom. Acetic acid (15%) was then poured into the beaker to just above the mesh containing the sample, and left for between four and six hours. The contents of the beaker were then washed over a sieve (63µm mesh) with warm water to dissolve the glycerol and dried in a warm oven. Residues were then examined using a reflected light microscope and reprocessed if necessary. The glycerol is used as a buffer to protect the radiolarians from the acetic acid. Specimens were readily removed from the matrix of these samples, however, their preservational state was generally poor, which appears to have been the result of the process of replacement of skeletons by calcite.

The advantage of using acetic acid rather than hydrochloric acid is that former has a much less vigorous reaction with $CaCO_3$ and may therefore be left unattended immediately. Furthermore, the gentle acidic attack may produce less damage to fragile skeletons.

2.5.2 Hydrochloric acid (HCl)

Hydrochloric acid was used on certain limestone samples to gauge the difference, if any, between it and acetic acid as a means of extraction. The limestones were treated in the same manner as the calcareous mudstone, described above (2.5.1). The end result was a similar observed faunal assemblage with perhaps slightly more damage to fragile species.

2.5.3 Discussion

Samples provided by Barkham for this study were processed using dissolution in acetic acid for the radiolarians and floating on bromoform to concentrate the conodonts present. The bioclastic content of the limestones varies between 10-80%. Those containing 80% radiolarian tests are defined as radiolarite and required very little processing, in fact only a few minutes boiling in water and sodium carbonate (Na_2CO_3) completely disaggregated such lithologies.

2.6.0 Further cleaning techniques

Further cleaning techniques are used for secondary preparation of radiolarians already processed and freed from their encapsulating matrix. These methods are necessary to remove particles which survived initial removal attempts and may obscure important taxonomic features. Again a mixture of physical and/or chemical treatment may be employed to achieve clean, particle-free specimens.

Ultrasonic vibrations have been used by a number of workers (Pessagno, 1977; Sanfilippo and Riedel, 1985; Urquhart, 1992) for the preparation of radiolarian samples. This technique was used on a few samples in an attempt to clean already processed and freed radiolarians. Ultrasonic vibrations were not found to be a successful method of removing particles, indeed this technique was found to damage specimens if left for too long in the vibrating bath. For a more detailed discussion of this technique see Urquhart (1992).

Boltovskoy *et al.* (1983) recommended that specimens in cavity slides have small amounts of 96% ethanol added and then rinsed to help remove particles. Furthermore, washing specimens in 96% ethanol and/or xylene improves contrast.

During the course of this investigation several techniques were used to clean already processed fossils. Individual specimens were placed in a plastic single cell microscope slide and then one of a number of substances were added. A few drops of either 10% hydrochloric, 10% acetic acid were added then left for a few hours. Specimens were then removed to another slide with a few drops of distilled water and gently stroked with a fine (OOO) paint brush to dislodge any particles still attached. This method appeared to be successful in removing debris, especially when individual specimens were brushed in distilled water in the final stage.

Oxalic acid $(COOH)_2$ may be employed as a bleaching agent of radiolarian skeletons. Secondary treatment of freed specimens by boiling in sulphuric acid (H_2SO_4) has successfully been used to clean radiolarians. The above two methods were not used during the processing of studied samples as these were considered dangerous and time consuming.

Secondary cleaning of assemblages or individuals undoubtedly improves the skeletons for photographic purposes. The one disadvantage is that the extra handling of the fossils can result in the damage or loss of individuals . Overall, there is still a lack of consistency in terms of the extraction of radiolarians. These variations in extraction of fossils may culminate in unsafe conclusions, as assemblage differences may be an artifact of processing. One possible way around this would be to adopt the system used by diatom workers. This method involves sending sample splits to other laboratories for comparative preparation and counting.

2.7.0 Photographic illustration

Illustration of radiolarians requires the ability to observe details of both the inner and outer structures. This may be achieved by a combination of SEM and light microscope photography. Broken specimens also allow SEM micrographs to be taken of internal structure, and this method is as important as illustration in the light microscope.

2.7.1 Picking and mounting

Following initial extraction and further preparation, dry sample residues were stored in paper residue bags for safety. All samples were separated into four size fractions (0-63μm, 63-150μm, 150-250μm, 250-500μm) using a standard nest of sieves. All size fractions were then picked with special attention given to the 63-150μm and 150-250μm size fractions. A Wild reflected light stereo binocular microscope was used for picking and initial examination of fossils. Individual specimens were removed from a gridded picking tray using a very fine (OOO size), moistened paint brush (preferably natural fibre) and placed into a single cell microscope slide. Picking each sample to ensure that a high proportion of the total assemblage is removed is essential in order to conduct taxonomic and biostratigraphic studies. Once the maximum number of specimens recoverable during picking which meant that no new taxa were being observed then separation to genus and species level was carried out. Up to 100 examples of each taxon were picked if a rich sample was encountered, however, if samples contained low numbers of radiolarians each size fraction was picked out (often amounting to five or more hours of picking). Before specimens were placed into the gridded slide a layer of water soluble glue was placed onto the slide surface and allowed to dry. In species where it was important to observe the external ornament a green vegetable dye was painted on the surface of the radiolarian. Species were then glued into place in one grid square per species with a moistened paint brush. If certain species or genera were found to consist of only a few individuals then the original residue was repicked in order to extract enough specimens for comparative purposes (at least four individuals). Furthermore, if a new species was suspected to be present more specimens were picked.

2.7.2 Mounting for the SEM

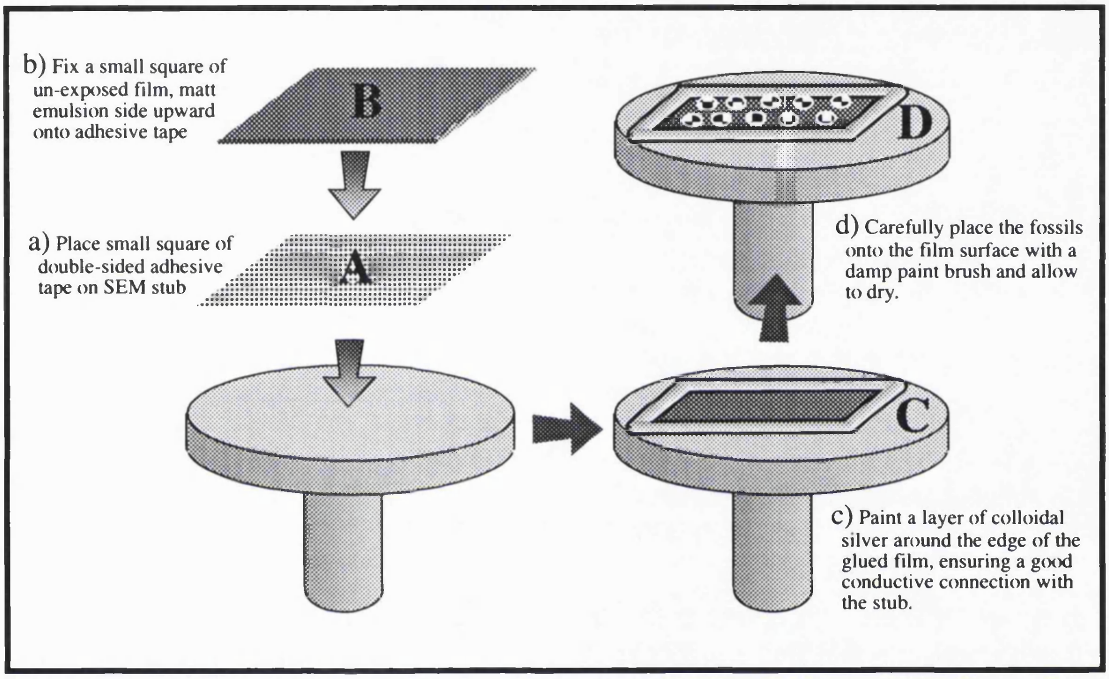
Several mounting techniques and materials may be found in the published literature for SEM microscopy. De Wever (1980) described a technique for the manipulation and mounting of radiolarians. After cleaning, he would place specimens in distilled water to prevent individuals from sticking together and to cushion the delicate fossils from damage. All picking would be carried out under water and individuals placed onto an SEM stub with a damp paint brush. The stub was previously coated with a thin layer of red nail varnish, which produced a smooth black background during photography and allowed good visibility when mounting specimens. De Wever (1980) then placed the stub, along with an open beaker of acetone inside an upturned dish. The acetone would soften the varnish, allowing the specimens to sink in and create a good connection with the stub. Although this is a cheap and simple method with easily available materials it was not used for the mounting of radiolarians onto SEM stubs because once fixed into the nail varnish specimens had to be exposed to acetone in order to move them, which is time-consuming and may leave droplets of varnish attached to the tests or soaked inside complex mesh tests. Specimens may also sink into the varnish too far and therefore not be very controllable.

(and Baumgartner, 1981)

A well-established method within the UCL Micropalaeontology Unit was used in this study. Double-sided adhesive tape is commonly used as a mounting medium, this material can, however, allow the specimens to sink into the glue during gold coating in the sputter-coater. Instead of the adhesive tape being used as the surface in contact with the fossils a small square of un-exposed film, matt emulsion side upwards, was fixed onto the adhesive tape (Text-fig 2.2). The film was cut so as to be smaller than the diameter of the stub and fixed firmly onto the stub. Colloidal silver was then painted around the edge of the film and stub in order to increase conductivity between the mounting medium and stub. Specimens could then be placed onto the film with a damp paint brush. The introduction of moisture to the emulsion forms a shallow temporary gel to which the fossils adhere. Individual radiolarians may then be easily moved or tilted into position with a damp paint brush. The emulsion provides a smooth background to the photographs. This material, unlike the nail varnish used by De Wever (1980), has the advantage of easy movement of specimens without the need to introduce acetone to soften the mounting medium.

2.7.3 SEM photography

Once mounted on the SEM stub a gold coating was deposited on the specimen in a Polaron sputter-coater. This process was carried out for 90 seconds initially, however, a degree of charging was noticed during much of the SEM investigation. Charging occurs if electrons in the beam are unable to complete the electrical circuit and reach earth, and the area in which they are held takes on an electrical charge (Chapman, 1986). This electrical charge will increase with time until a it is able to jump to an earth which manifests itself as bright interference on the micrograph taken. Stubs were recoated up to three times in an attempt to reduce charging. This effect, which induces an halo and lines across the micrograph, is commonly encountered by radiolarian workers, whichever mounting technique and materials are used. Several reasons for the occurrence of charging have been postulated and these include: poor electrical contact of specimens to stubs, size and shape of radiolarians, chemical composition of radiolarians



Textfig. 2.2 Preparation technique for SEM stub for illustration in this study.

etc.. During the course of this investigation two different SEM's were used. Initially a Jeol T200 instrument was used together with a Polaron sputter-coater. These machines were later replaced by a Zeiss DSM 940 SEM and a Nannotech SEMPREP 2 sputter-coater. The coating time was reduced to approximately 30 seconds and, together with the new microscope, charging was almost entirely eliminated.

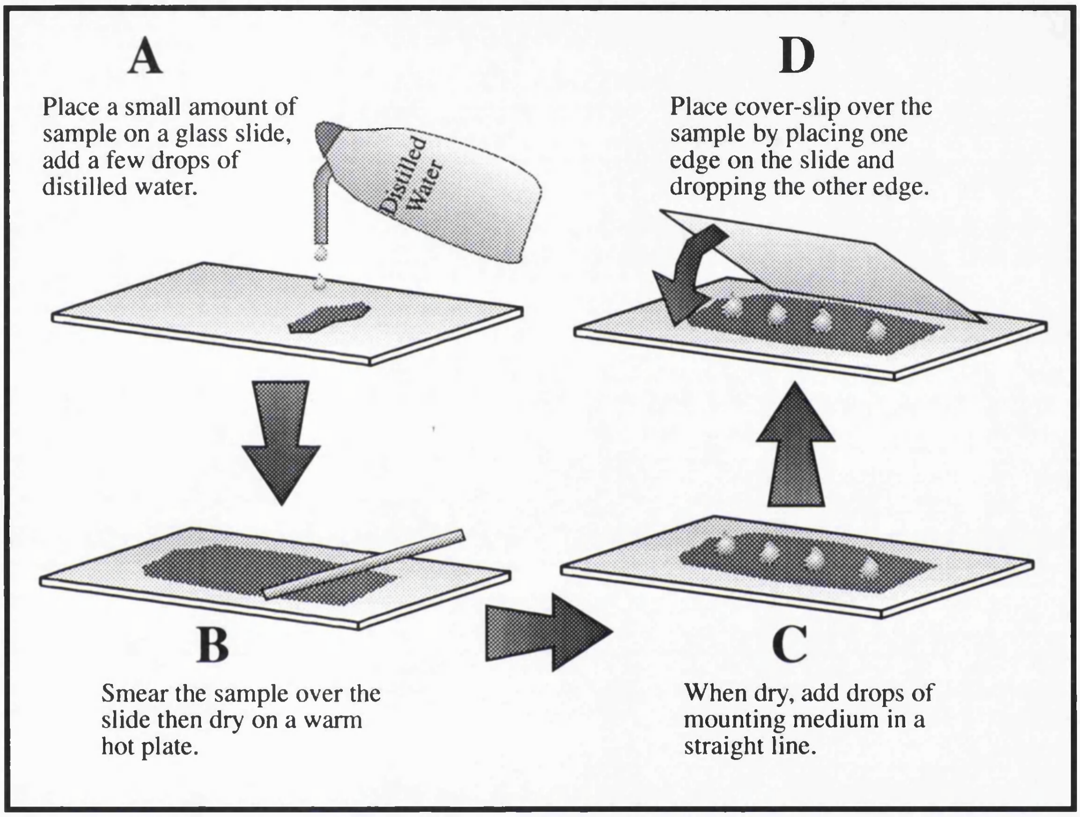
2.7.4 Backscattered electron emission (BSE)

The relatively new technique of using a backscattered electron emission (BSE) image was used and produced excellent charge-free results in the SEM. During normal use of the SEM high energy electrons are conducted away from the specimen via the gold layer coating it. These electrons, if allowed to build up on the surface of the specimen and can cause charging as the area in which they amass takes on an electric charge. Radiolarians may be more susceptible to charging as a result of the atomic number of silica, the material most often forming the test. A solid state backscatter detector, available for about the past eight years, is needed to detect the current flow and so produce an image. Electrons which pass inside the specimen are re-emitted from the specimen and have a 'low energy' i.e. up to the incident beam energy. The emission of backscattered electrons from a specimen, is related to the atomic number of the material involved, the higher the atomic number the higher the backscatter coefficient (Chapman, 1986). The image produced is of lower contrast than images produced during normal SEM photography, however, these may be enhanced to give high quality micrographs.

2.7.5 Mounting for the transmitted light microscope

Siliceous microfossils have a refractive index of RI=1.435-1.455mm if preserved as opaline A silica, RI=1.485mm for cristobalite and RI=1.544-1.553mm for quartz. The mounting medium used to observe radiolarians should have an higher refractive index than the fossils in order to give contrast and a clear image. Norland Optical Adhesive (NOA) RI=1.54)) was used as a mounting medium during this study.

A small quantity of prepared sample was placed on a glass slide to which was added a few drops of distilled water. The sample was then smeared over the entire surface of the slide and placed on a warm hot-plate to thoroughly dry. Static electricity held the fossils in position and a few drops of the mounting medium (NOA) were added. In order to minimise the chances of trapping air bubbles in the mounting medium four drops of



Textfig. 2.3 Smear slide preparation technique

adhesive were placed on the slide in a line (Textfig 2.3). The cover-slip (22 x 50mm) was then placed on the slide at an angle from one side to the other. This technique forces air bubbles to one end of the slide, any remaining air may be removed by tilting the slide and gently pressing the bubble towards the edge of the cover-slip with a tooth pick. Curing of NOA is achieved by placing the slide under an ultra violet lamp for 10-20 minutes.

2.7.6 Viewing in the SEM and light microscopes

In some instances it is necessary to view the same specimen in the SEM and the light microscope in order to take advantage of both techniques ensuring correct identification or description of the taxonomic features. It is desirable to complete photography in the light microscope first as specimens are not coated for viewing for this technique. SEM photography may be carried out first, however, this involves the use of strong chemicals to remove the gold layer which is not always completely successful. During this study specimens were selected, viewed in the light microscope while in immersion oil then cleaned in methylated spirit. These were then mounted for viewing in the SEM in the usual way. A few specimens were lost as a result of cleaning or moving between mounting media.

2.7.7 Discussion

For the purposes of good illustration it is necessary to use SEM photography of the external features of radiolarians together with broken specimens which show internal structure, as well as light microscopy. Techniques allow both types of photography to be utilised successfully. On occasion specimens were deliberately broken in order to view their internal structure. De Wever (pers. comm., 1992) described a technique for breaking specimens used by Dumitrica and himself. This involves placing a drop of Canada Balsam on a specimen and then, after curing, slicing the fossil with a razor blade. This technique together with simply breaking specimens underwater using a scalpel was undertaken on the family Patulibracchiadae in order to resolve the internal canal structure of their arms.

Distinct variations in the faunal diversity of closely spaced samples occurred. Couplets of marls and calcilutites were sampled from as many sections as possible and in most cases the marls produced more diverse radiolarian assemblages. This could be a result of initial preservation, subsequent diagenesis or less harsh processing procedures necessary for marls. Shales exhibited variation in terms of assemblage content. Generally radiolarians were well-preserved, however, tests tended to be very much more brittle than those radiolarians preserved in other lithologies. For a full list of the preparation techniques used on each sample refer to Chart 1 (in sleeve).

Chapter 3

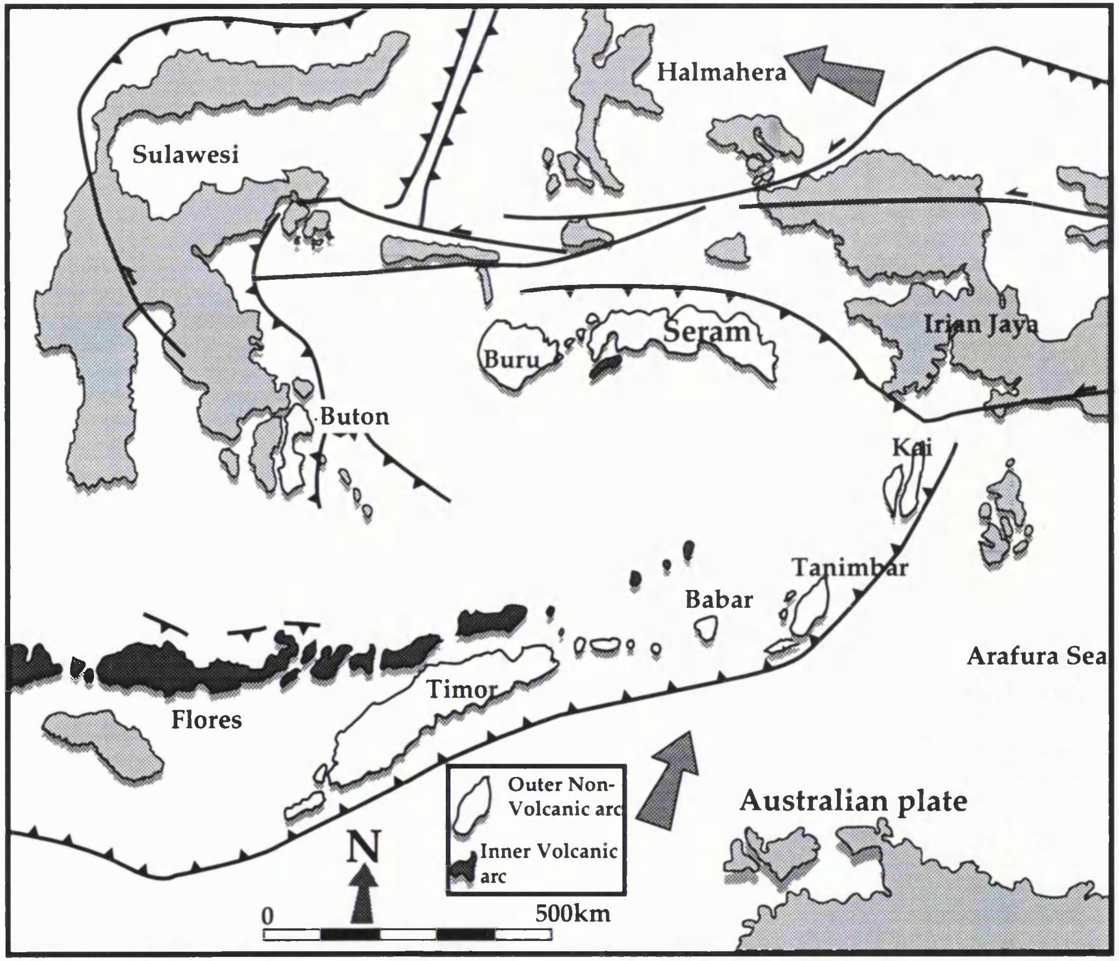
Regional setting and geology of Timor

3.1.0 Introduction

It is generally agreed that Timor and other islands of the Banda Arc form a collision zone between the Australian continental shelf and the Banda Arc-Trench system (Milsom and Audley-Charles, 1986). Three plates are involved in this complexly deforming region: the Philippine Sea Plate, moving west toward Southeast Asia; the Southeast Asian Plate, which is almost stationary in the hot-spot reference frame (De Mets *et al.*, 1990), and the Indo-Australian plate; which is moving north. The U-shaped Banda Arc is the result of this collision zone. The Indo-Australian Plate consists of two parts of which the Australian part is the most significant in this study. The northern margin of Australia consists of a core of Archaean rocks overlain by younger material. Phases of rifting throughout the Palaeozoic and Mesozoic displaced slivers of Australian continental margin northwards. During the Cenozoic (Pliocene) the leading edge of the Australian passive margin collided with the Banda Arc. Today the Banda Arc is a complex double arc system with an inner volcanic and an outer non-volcanic arc, and it is the sediments found on the outer non-volcanic part which are studied in this project (Textfig.3.1).

3.2.0 The early evolution of Tethys and its southern margin

Neumayr (1885) and Suess (1893) conceived the concept of Tethys and recognised the Mesozoic seaway in the sediments now forming the Alps and Himalayas. This east-west trending ocean, as recognised by the above authors, was related to a rearrangement of plate boundaries in the Late Triassic and Early Jurassic. Early rifting leading to the evolution of the Jurassic-Cretaceous Tethyan ocean was clearly discordant in time and space to the pre-existing palaeotectonic pattern. Tensional movements occurred over a considerable period with many aulacogens produced and, unlike other movements, took place in a subsiding, marine environment. The Ladinian was a time of thick carbonate sedimentation interspersed with radiolarian cherts, volcanics and turbidites. Overall, the general concensus is that Tethys was



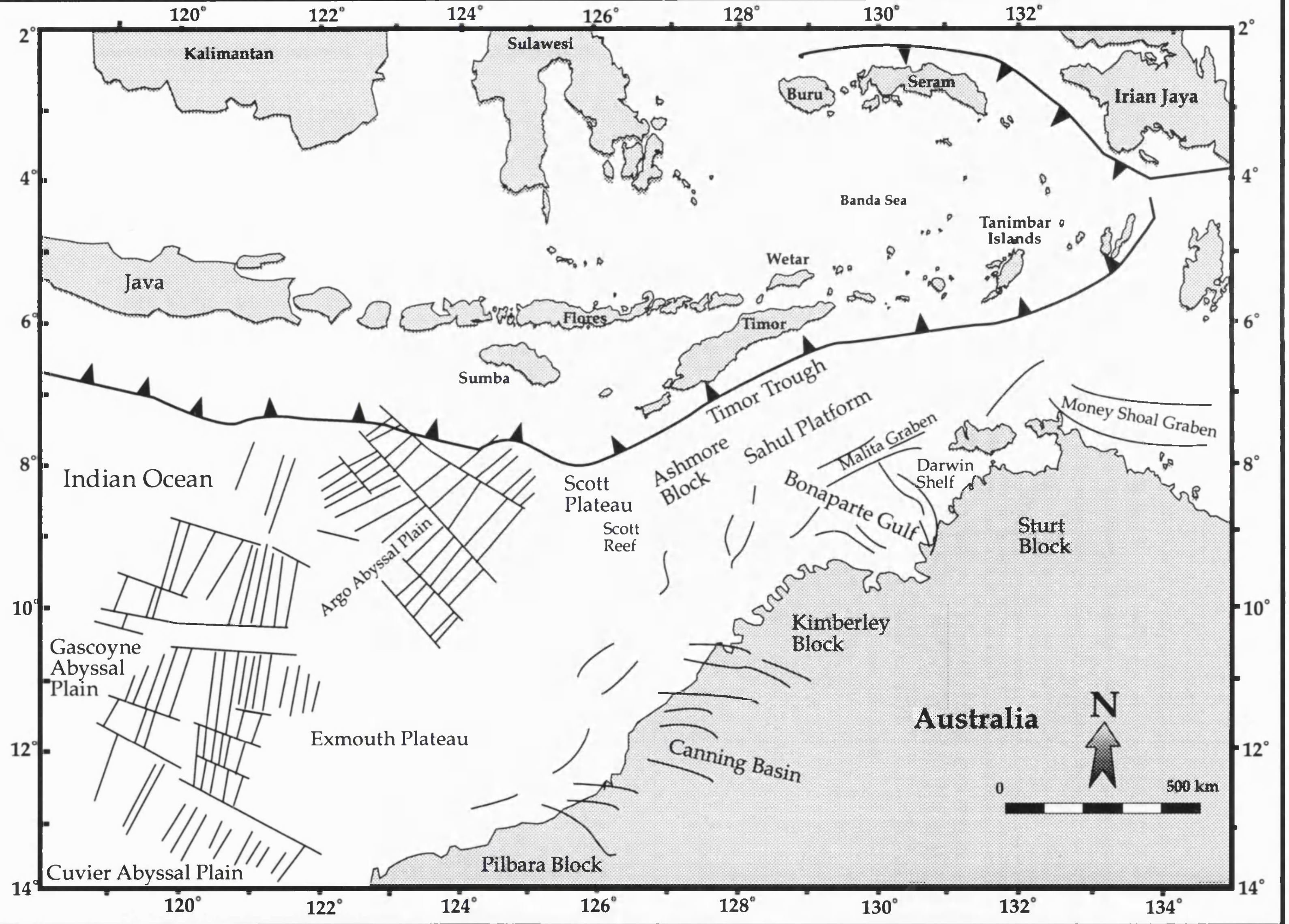
Textfig. 3.1 The Islands in the Banda Arc (including Timor, Babar and Buton.

limited in size to a zone of small interlinked ocean basins (some existing for long periods of time) similar to the Red Sea and interspersed with microcontinents. Furthermore, Tethys is not thought to be part of Palaeotethys, but formed along the southern continental margin of this earlier ocean.

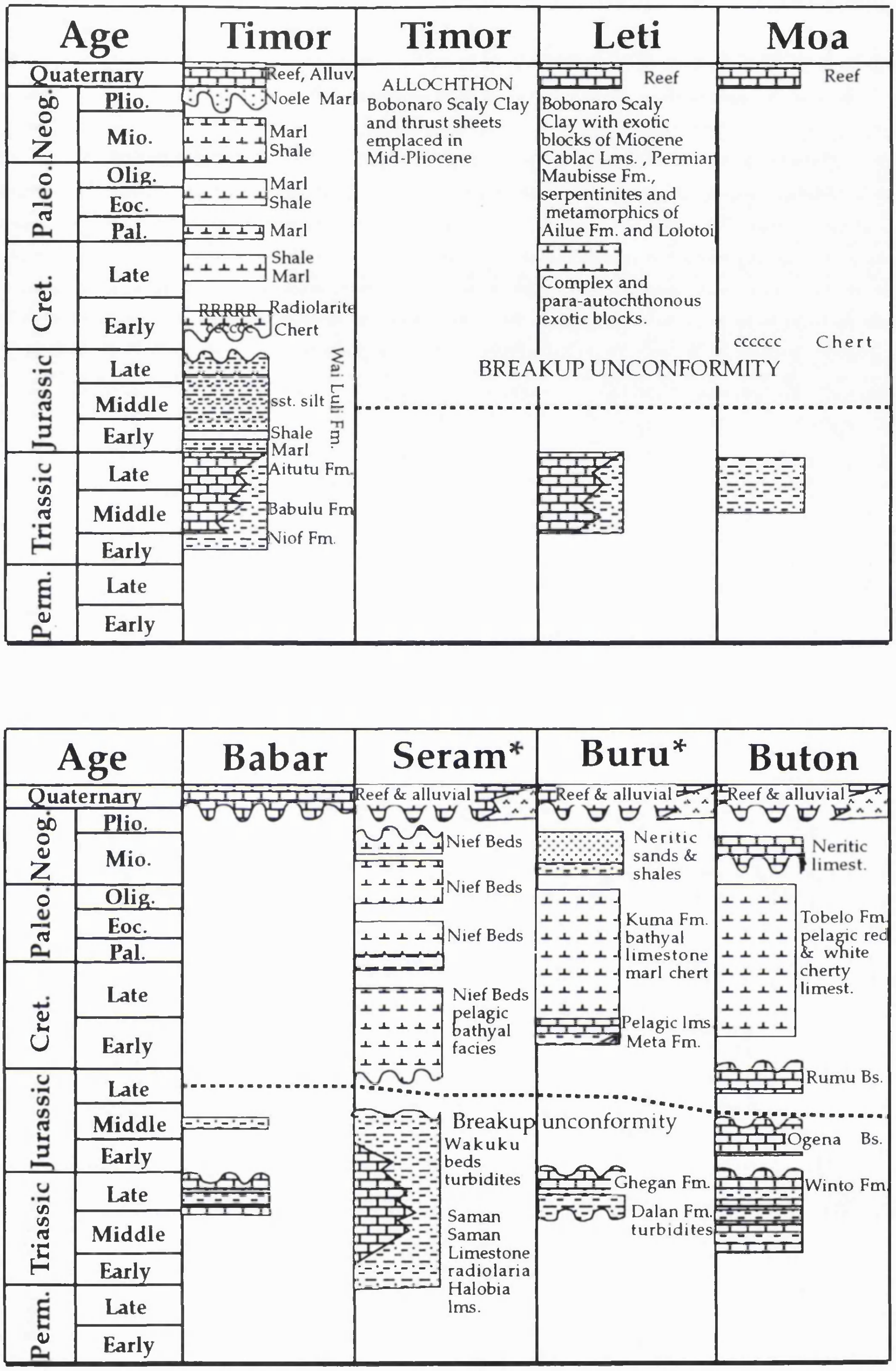
The margin of northwest Australia is thought to have come into being in the Early Palaeozoic as part of Gondwana. At some time in the Cambrian to Ordovician (575-510 Ma), break-up of the northwest part of Gondwana is believed to have resulted in the separation of Eurasia thus forming Tethys with Australia on the southern margin.

A mid-Permian episode of rifting displaced Australian-Gondwana continental fragments, moving these to the north into Asia. Further phases of tectonic activity during the Triassic and Jurassic were responsible for the formation of the present day configuration of northern Australia and central New Guinea. This Jurassic rifting event led to the creation of the Argo Abyssal Plain, the oldest part of the Indian Ocean (Textfig. 3.2). Large scale tectonic activity led to the further fragmentation of Gondwana, with Australia and India breaking away from Antarctica in the Cretaceaous. During the Cenozoic the majority of the overlying sediment pile underwent complex thrusting and folding, throwing up a mountain belt expressed by the islands of the Outer Banda Arc, New Guinea, East Sulawesi and Buton. Evidence of the rifted continental margin, containing pre-rift and post-breakup sequences may be observed on many of the islands within this group. An important implication is the northward drift of such continental blocks (Audley-Charles 1988) and the subsequent collisions with South East Asia and earlier rifted Gondwana fragments.

A remarkable similarity in Mesozoic sequences from places as widely spaced as Timor, Buton and Seram attest to the similar geological history shared by the these islands (Textfig 3.3), indeed various characteristic facies belts (e.g. Pötschen, Pedata and Zlambach formations of Europe = Aitutu Formation as observed on Timor) may be observed all along the margin of Tethys from Timor in the east to the Alps in the west. Two important features of the ability to correlate in Southeast Asia may be noted. The first is the predominance of siliciclastic sediments observed in the pre-breakup sequences of both Northern Australia and the islands of the Outer Banda Arc. The second is a huge reduction in the siliciclastic content of post-breakup sediments coinciding with the onset of deep water oceanic conditions.



Textfig. 3.2 Large scale geological structures on the Northwest Shelf of Australia



* - not visited during this study

Textfig. 3.3 Mesozoic sequences occurring on the islands of the Banda Arc, Indonesia.

3.3.0 The geology of Timor

3.3.1 Introduction

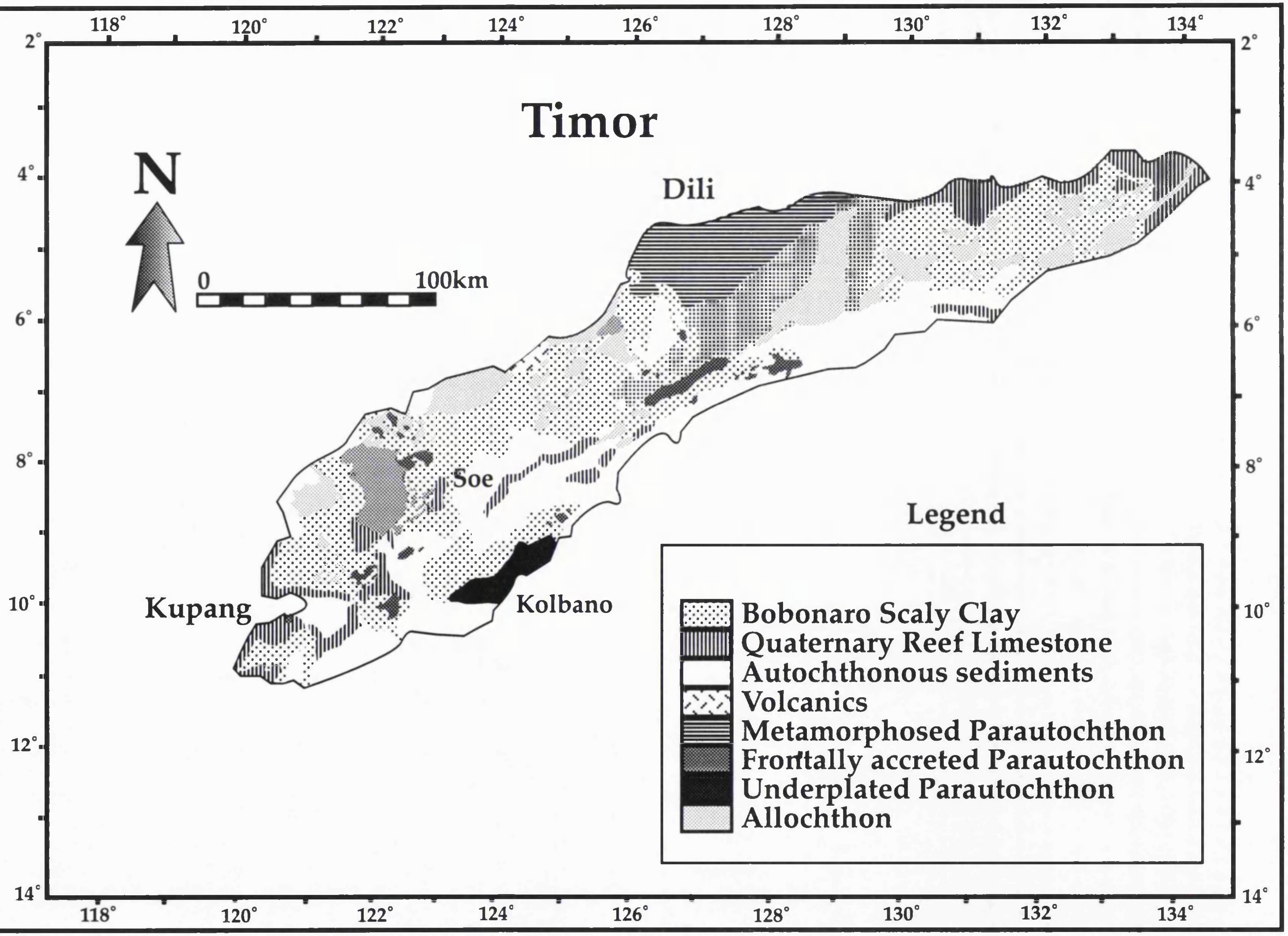
Timor is the largest of the Lesser Sunda Islands and has therefore attracted a great deal of geological exploration and research (Textfig. 3.31, Textfig. 3.32). Political and geological complexity together with difficulties in carrying out fieldwork have led to confusion in the literature. The geology of Timor (Textfig. 3.4) is usually divided into six parts, reflecting a general consensus.

1) Allochthon
2) Unmetamorphosed Parautochthon
3) Metamorphosed Parautochthon
4) Autochthon
5) Bobonaro Scaly Clay
6) Volcanics

3.3.2 Allochthon

The allochthon is divided into four parts: 1) the Mutis-Lolotoi metamorphic volcano-sedimentary sequence, 2) the ultra-basic and basic igneous rocks, 3) the Palelo Group of deformed sediments and 4) the overlying Tertiary units. Tectonic contacts occur between the rocks in the above groups.

The Mutis Metamorphic Complex (in West Timor) is correlated with the Lolotoi Metamorphic Complex in the east and consists of amphibolite, pelitic gneiss, granulite, mylonite, quartzite, schist, phyllite and slate (Audley-Charles, 1968). This unit (Mutis-Lolotio) has an inverted metamorphic gradient. A Mesozoic orogenic event (118±38 Ma interpreted as the acme of metamorphism (Sopaheluwakan, 1990)) is believed to have metamorphosed a sedimentary pile. Closely allied to the Mutis-Lolotoi Complex is the Palelo Group of metamorphosed and deformed agglomerates, tuffs, cherts and limestones of Late Cretaceous to Eocene age. Two limestone formations (Noil Toko and Cablac Formations) unconformably overlie the Mutis-Lolotoi Complex and Palelo Group.



Textfig. 3.4 Basic geological map of Timor (after Audley-Charles (1968) and Rosidi *et al.* (1979))

The metamorphic complex is believed to formed when oceanic lithosphere deformed near a spreading centre (Sopheluwakan, 1990). Thrusting produced the metamorphic inversion which was preserved by rapid uplift and obduction onto the Australian passive margin.

3.3.3 Unmetamorphosed Parautochthon

The rocks of the Unmetamorphosed Parautochthon include those studied during this project (Aitutu and Wai Luli Formations (Textfig. 3.5)) and were first defined as the 'parautochthon' by Audley-Charles (1968). These sediments are of Late Palaeozoic to Cenozoic age, formed a cover on the Australian continental margin and are said to have Austral affinities. The oldest sediments are the Permian Atahoc, Maubisse and Cribas Formations of which the Maubisse, Aitutu and Wai Luli have recently been studied by Barkham (1993). One of the aims of Barkham's (1993) study was to determine whether the Maubisse Formation was allochthonous or autochthonous.

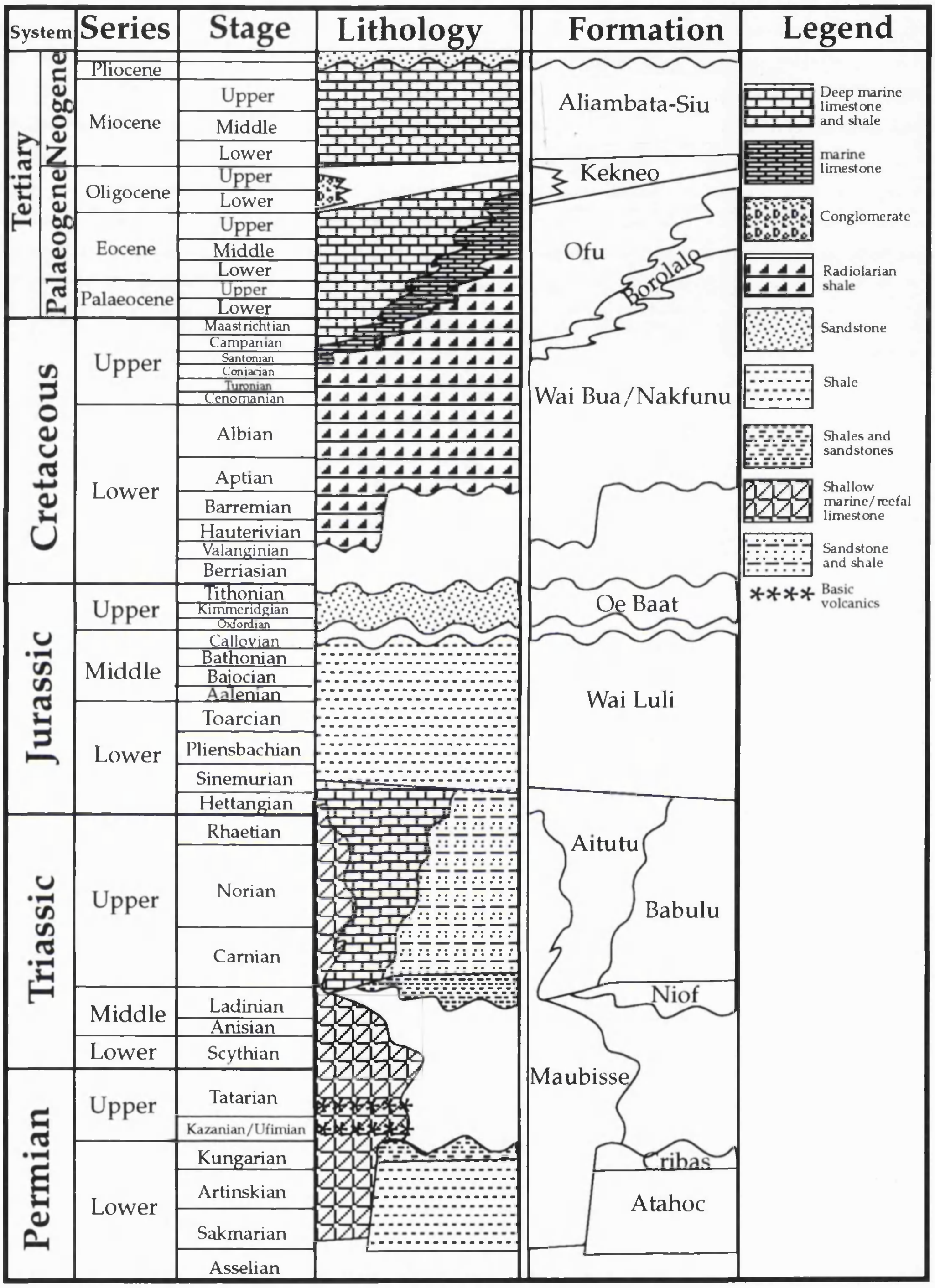
3.3.4 The Atahoc and Cribas Formations

For a detailed description of the oldest part of the Parautochthon (the Cribas and Atahoc Formations) see the following references:

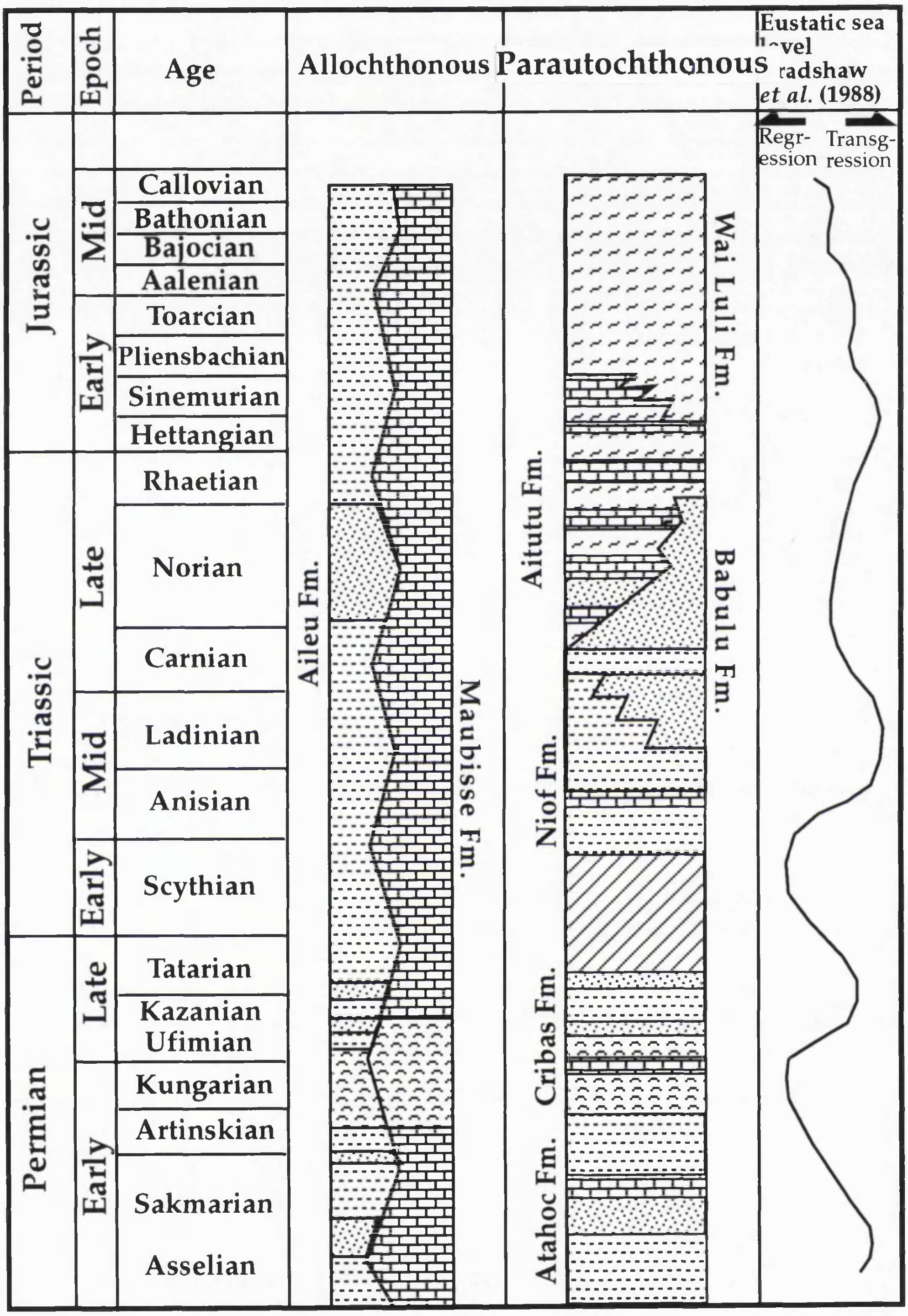
1) Lower Permian (Atahoc Formation)- Audley-Charles (1968); Rosidi *et al.* (1979); Bird and Cook (1991).
2) Lower Permian (Cribas Formation)- Audley-Charles (1968); Chamalaun (1977); Bird and Cook (1991).

3.3.5 The Maubisse Formation

Barkham (1993) concluded that the Maubisse Formation formed an integral part of the Permo-Triassic of Timor and therefore is not allochthonous (Textfig. 3.6). Epicontinental sediments were deposited on Gondwanaland (Sakmarian) prior to breakup (in the Artinskian/Kungurian). The evolving intra-cratonic basin produced fault controlled sedimentation with pillow lavas erupting in the rift. Various sedimentary regimes produced condensed sequences in the Late Permian and restricted sequences in the Early to Mid Triassic, followed by deep water sediments in the Late Triassic. During this period a marked change in climate occurred beginning with periglacial water



Textfig. 3.5 Stratigraphy of the Timor Parautochthon (After Charlton, 1989)



Textfig. 3.6 Permo-Triassic stratigraphy of Timor with eustatic sea level curve (after Audley-Charles (1968); Barkham (1993).

temperatures in the Early Permian, sub-tropical in the late Early Permian and tropical in Late Triassic times.

A period of Late Jurassic rifting signalled the breakup of Gondwanaland, positioning the Permo-Triassic sediments on the leading edge of the continental margin. This drifting passive margin became an active margin on entering the collision zone (in the Miocene (Abbot and Chamalaun, 1981)) with the Southeast Asian plate to the north. The pattern of these sediments indicates accretion to the overriding plate by underplating, and they were separated from frontally accreted sediments by a décollement at the Jurassic breakup unconformity (Barkham, 1993).

3.3.6 The Aitutu Formation

There is general agreement that the Aitutu Formation is autochthonous and was deposited on the Gondwana continent in approximately the same position (relative to Australia) that it now occupies. The Aitutu Formation consists of dense radiolarian calcilutites interbedded with shales. Three members have been described: 1) the Tallibelis Member, introduced by Audley-Charles (1968) and thought to be Norian in age, and is now believed to be Rhaetian, forming a transition zone between the Aitutu Formation and the Wai Luli above; 2) The Babulu Member, which is a deltaic turbiditic sandstone and has variously been placed above, below and coevally with the Aitutu Formation; 3) The Meto Member, was described by Barkham (1993) and divided into a three part cycle(s) consisting of limestones (wackestones and packstones, with rare grainstones with mainly radiolarian grains) forming couplets with darker marls or shales (for a more detailed description of the Aitutu and Wai Luli Formations see Chapter 4). The Aitutu Formation is now thought to be ?Ladinian to Early Jurassic in age and is believed to be at least in part coeval with the deposition of the Maubisse Formation (Textfig. 3.5).

3.3.7 The Wai Luli Formation

Audley-Charles (1968) was the first to separate the Wai Luli from the 'autochthonous Mesozoic' of Grunau (1953). Barkham (1993) recognised two microfacies groups: 1) radiolarian wacke/packstone, 2) carbonate mudstone. This formation is believed to be Early to Mid Jurassic in age (for a more detailed description of this formation see Chapter 4).

3.3.8 Upper Jurassic and younger part of Parautochthon

For detailed descriptions of the Cretaceous and younger sediments of the parautochthon see the following references:

1) Upper Jurassic (Oe Baat Formation) - Charlton (1987); Charlton and Suharsono (1990); Charlton and Wall (1994).
2) Cretaceous (Wai Bua/Nakfunu Formations) - Audley-Charles (1968); Charlton (1987); Charlton and Wall (1994).
3) Upper Cretaceous-Eocene (Borolalo Formation) - Audley-Charles (1968); Charlton (1987); Charlton and Wall (1994).
4) Upper Cretaceous-Eocene (Ofu Formation) - Audley-Charles and Carter, (1972); Charlton (1987); Charlton and Wall (1994).
5) Miocene-Pliocene (Aliambata-Siu Formation) - Audley-Charles (1968); Kenyon (1974); De Smet *et al.* (1990); Charlton and Wall (1994).

3.3.9 Metamorphosed Parautochthon

The Aileu Formation (Textfig. 3.4) crops out only in East Timor and consists of metamorphosed siliciclastics and volcanics (at sub greenschist to amphibolite facies). Radiometric dating on the Aileu Formation gave an age of 8 Ma for the metamorphism (Berry and McDougall, 1986) which predates the Pliocene deformation preserved in the sediments of Timor. The Maubisse Formation is believed to be an umetamorphosed relation of the Aileu Formation (Berry, 1979; Berry and Grady, 1981; Charlton *et al.* 1991) and so the metamorphosed parautochthon is associated with the parautochthon. This view is supported by the discovery of a number of Permian to Upper Jurassic fossils (Gageonnet and Lemoine, 1958) extending the relationship of the Aileu Formation to a lateral equivalent of the Maubisse (Permian) to Wai Luli (Jurassic) formations. The deformation and metamorphism is believed to have occurred in a Mid-Late Miocene (8 Ma.) arc-continent collision of the Permian to Jurassic Australian shelf sediments when these arrived at the subduction zone.

3.3.9.1 Autochthon

Following a Mid-Miocene break in sedimentation (and unconformity) believed to have occurred across Timor (Audley-Charles, 1968; De Smet *et al.*, 1989) the Viqueque

Group was deposited in basins brought into being by orogenic activity. Parts of the Viqueque Group (Batuputih Limestone) have been regarded as autochthonous (Kenyon, 1974) by some and parautochthonous by others (Rosidi *et al.*, 1979; Charlton, 1989), and may in fact belong to both (parautochthon and autochthon). In West Timor the Viqueque group consists of the Saboe, Noele, Noil Lakoe Marl, Soe Noil Besi formations. Elsewhere (eastern Timor) the Viqueque Group consists of sands, conglomerates, reef limestones and lacustrine deposits.

3.3.9.2 Bobonaro Scaly Clay

The Bobonaro Scaly Clay was recognised by Audley-Charles (1965, 1968) and described as consisting of two lithological constituents: 1) the scaly clay matrix (a highly sheared scaly clay), and 2) the exotic material (randomly distributed blocks in the scaly clay matrix ranging in size from silt grade to 500m length). This lithology is commonly encountered on Timor and occurs on many of the other islands in the Banda Arc.

This unit and its various interpretations have attracted a great deal of controversy. Audley-Charles (1965, 1968) interpreted the unit as an allochthonous scaly clay olistostrome with an intimate association with the Maubisse Formation. Hamilton (1979) described the Bobonaro as a tectonic mélange formed by intense shearing as a result of repeated forearc thrusting. Barber *et al.* (1986) recognised difficulties in the above interpretations and so re-interpreted the Bobonaro Formation as being the product of shale diapirism (expressed as mud volcanism at the surface). Mud volcanoes are commonly found on Timor, and have been observed by the author on Babar. The introduction of exotic blocks into the clay matrix is the result of high pore fluid pressure in wet shales at depth. Thrusting over-pressurises the wet shale which flows along fault planes washing out blocks and randomly mixing these blocks in the matrix. The texture of the scaly clay is then overprinted as the diapiric activity abates and during any subsequent shearing.

3.3.9.3 Volcanics

The Manamas Formation crops-out on the northern coast of Timor and consists of pillow lavas (andestic and basaltic), breccias and tuffs. These rocks have been interpreted as upthrusted forearc material by Bennett (1975), and Charlton *et al.* (1990).

The Manamas Formation has also be considered to be part of the Flores-Atauro-Wetar arc by Tjokrosapoetro (1983).

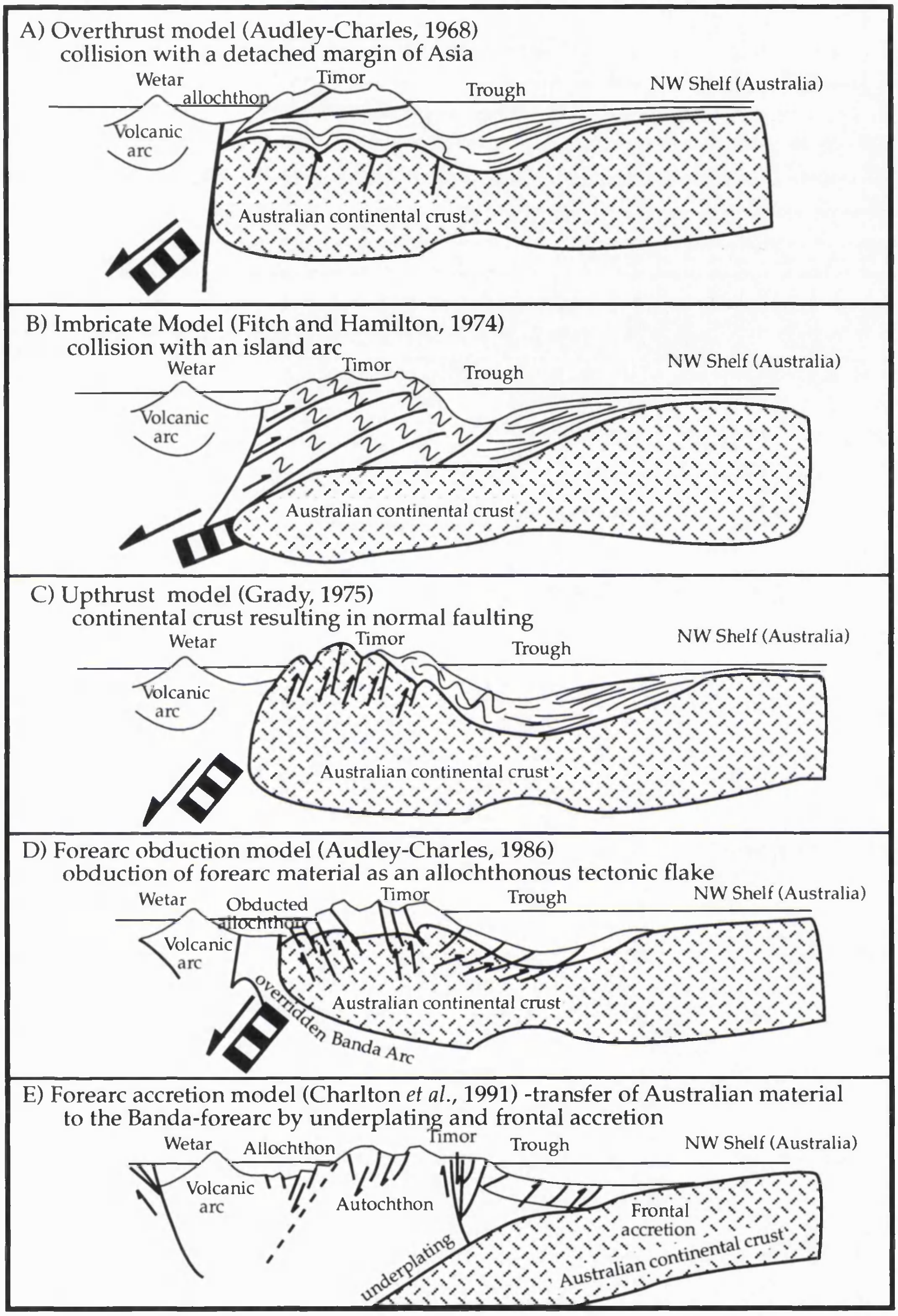
3.4.0 The recent evolution of the Banda Arc islands

3.4.1 Introduction

The evolution of the Banda Arc Islands, especially that of Timor, over the last few million years has been the subject of a great deal of research and debate. A number of authors (Audley-Charles, 1968, 86, 88; Fitch and Hamilton (1974); Grady (1975); Barber *et al.* (1977); Charlton (1987); Karig *et al.* (1987) and Charlton *et al.* (1991)) have carried out a great deal of research and have produced a number of models to explain the present configuration of the rocks found on Timor and other islands in the Banda Arc (Textfig 3.7).

The Sunda and Banda Arcs are surface expressions of the continuous line of continent-island arc collision. Prior to the collision, the Indonesian subduction zone extended eastwards into the region that is now the southern Banda Arc (Johnson *et al.* 1981). The edge of the Australian continental margin entered the subduction zone only about 3 m.y. ago. A wedge of deformed continental margin sediments migrated up the continental slope and the relative motion between the plates dramatically slowed. Further compression has been taken up by the subduction zone causing thickening of oceanic crust and uplift of the deformation wedge, producing islands such as Timor.

Milsom and Audley-Charles (1986) summarised the collision history of Timor (Text-fig. 3.8) and describe the clear difference between the deep-water, continental slope and rise setting in which the Australian para-autochthonous sediments were laid down and the shallow-water lithologies of the allochthonous thrust sheets. This difference was present until the end of the Miocene, when the rapid onset of deformation occurred. Thrust sheets were emplaced during the Middle Pliocene with the compressional folding of the Australian margin para-autochthon and overlying thrust sheets occurring over a period of 2 Ma (Milsom and Audley-Charles, 1986). Post-collisional movements have a strong vertical element which may be observed in the over-steep topography of the island. Different rates of vertical movement have been calculated for different parts of Timor. Pleistocene reefs are 1200 m above sea level in some areas, and for central West Timor a rate of 3.3 mm yr^{-1} have been calculated by Tjokrosapoetro (1978).


A) Overthrust model (Audley-Charles, 1968) collision with a detached margin of Asia

B) Imbricate Model (Fitch and Hamilton, 1974) collision with an island arc

C) Upthrust model (Grady, 1975) continental crust resulting in normal faulting

D) Forearc obduction model (Audley-Charles, 1986) obduction of forearc material as an allochthonous tectonic flake

E) Forearc accretion model (Charlton *et al.*, 1991) -transfer of Australian material to the Banda-forearc by underplating and frontal accretion

Textfig. 3.7 Tectonic models for the Neogene evolution of Timor (after, Barber, 1979; Audley-Charles, 1986; Charlton *et al.*, 1991).

Age BP	Stratigraphic and structural events on Timor	Tectonic events
~ 0 Ma	Uplift of Pleistocene coral reefs and alluvial terraces	Uplift of collision zone ~3 km
~ 2 Ma	Deposition of coral reefs and alluvium during the Pleistocene (N 22-23)	
~ 2 Ma	**Local angular unconformity**	
	Widespread subaerial erosion Gentle folding of Viqueque turbidites	
	Deposition of Viqueque turbidites (Noele Marl Formation-Late Pliocene-Early Pleistocene N.21-22) with subaerial erosion in northern Timor	
	Deposition of Sabaoe Limestone Formation (Late Pliocene N 21) in shallow water	
	Deposition of upper part of Batu Putih Limestone in deep water (Late Pliocene N 21)	
~ 3 Ma	**Local angular unconformity**	Compressionof collision zone Subsidence of autochthon
~ 3 Ma	(Cessation of volcanic activity in Atuaro and Wetar of inner Banda Arc)	
~ 3.5 Ma	Emplacement of thrust sheets with overlying Bobonaro Scaly Clay olistostrome and lower part of the Batu Putih Limestone in the Middle Pliocene (N 18-19)	
~ 4 Ma	Deposition of lower part of Batuh Putih Limestone on the Bobonaro Scaly Clay in the Early Pliocene (N 18-19)	
	Erosion of para-autochthon Folding, faulting and local imbrication of para-autochthon	
~ 5 Ma	Deposition of youngest member of para-autochthonous Australian continental margin facies (Early Pliocene N 18)	
~ 7 Ma	Sedimentation of the allochthonous elements changes from shallow water Cablac Limestone (early Miocene N 8) to deep water Miomaffu tuffs (Late Miocene N17)	

Textfig. 3.8 Summary of late Cenozoic stratigraphy and stratigraphic events in Timor (after Milsom and Audley-Charles, 1986).

Various gravity surveys have outlined a series of positive and negative anomalies with the same shape as that of the Banda Arc. The large gradients are across the non-volcanic islands of the Banda Arc. Regional surveys have shown isostatic disequilibrium which Milsom and Audley-Charles (1986) attribute to isostatic readjustment in the form of post-collisional vertical movements. The mechanism postulated for this is the detachment of the oceanic portion of the lithosphere from the continental part.

Over the past few million years the arrival and collision of the Australian margin has formed anomalous subduction, in that continental lithosphere has subducted under oceanic lithosphere to a depth of over 100km (Richardson, 1993). A collision complex was thus formed and is observable over a narrow belt more than 2000km in length.

3.5.0 Models explaining the present geological structure of Timor

3.5.1 Introduction

There have been an number of models proposed for the evolution of the outer arc ridge based on different interpretations of the geology of Timor (Textfig. 3.7). The outer arc ridge in the Banda Arc is thicker than that of the Sunda Arc and is due to a thicker sediment pile and the collison of the Australian continental margin. Subduction along the Timor region of the Banda arc is believed to have ceased during the Mid Pliocene (Johnston and Bowin, 1981) as a result of the introduction of continental material into the collision zone. Volcanism appears to have ended in the islands to the north of Timor and the collision seems to now be reflected by rapid uplift in some parts of Timor. Volcanism is still occurring to the east and west of Timor, and Charlton (1989) believed that this was due to the Australian continental margin entering the collision zone in this area before others.

3.5.2 The Overthrust Model

Audley-Charles (1968), Carter *et al.* (1976) and Barber *et al.* (1977) refined the overthrust model first postulated by Wanner (1913) (Textfig. 3.7(a)). In this model two sedimentary sequences are believed to have been deposited over the same time period (Permian to Pliocene). Australian continental margin material forms the parautochthon the other sequence is thought to be allochthonous and thrust over the parautochthon into its present position in the Pliocene.

3.5.3 The Imbricate Model

This model (Textfig. 3.7(b)) was introduced by Fitch and Hamilton (1974) and proposed that Timor is entirely formed by Australian continental margin material which has been imbricated and accreted to the hanging wall of the subduction zone and forms a mélange.

3.5.4 The Upthrust Model

Grady (1975) first proposed this model (Textfig. 3.7(c)) and was later followed by Chamalaun and Grady (1978) and Berry and Jenner (1982). All sediments are regarded as Australian margin material (autochthonous). Thrusting in this model is not believed to be significant. The mechanism introducing Australian continental crust into the subduction zone is thought to be high angle normal faulting resulting from differential isostatic uplift.

3.5.5 The Forearc Model

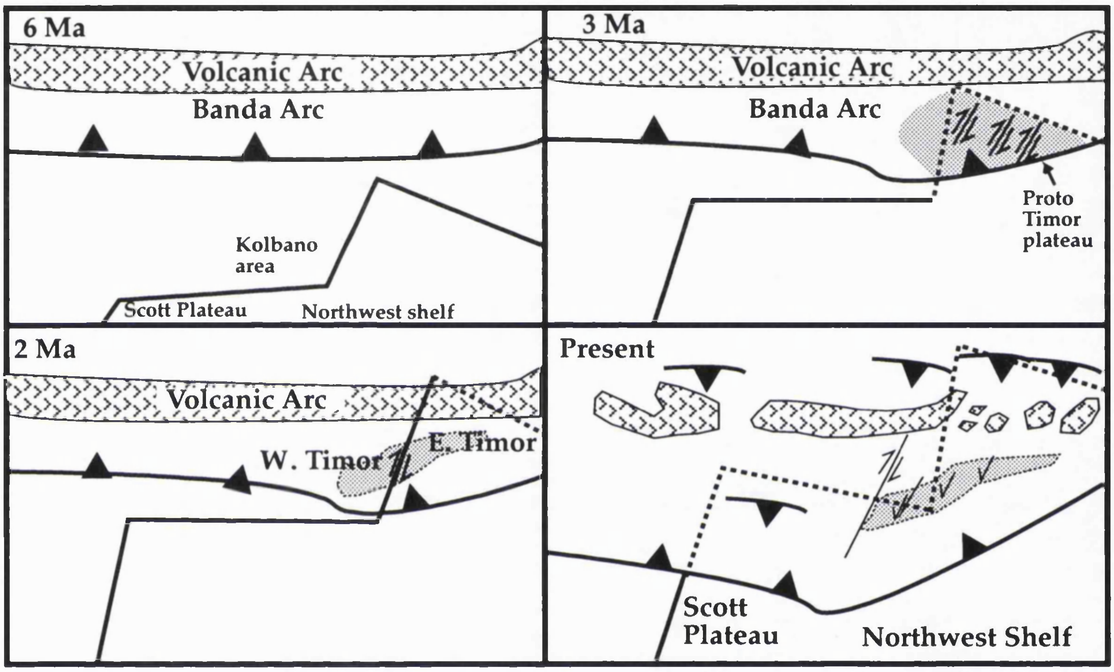
Proposed by Audley-Charles (1981) and refined by Price and Audley-Charles (1983) and Audley-Charles (1986) and is a development of the earlier overthrust model. The idea that the allochthon was obducted as a 'tectonic flake' from the forearc basement is the mechanism for this model. The rebound of this Australian lithosphere allowed the reversal of subduction (Textfig. 3.7(d)).

3.5.6 The Forearc Accretion Model

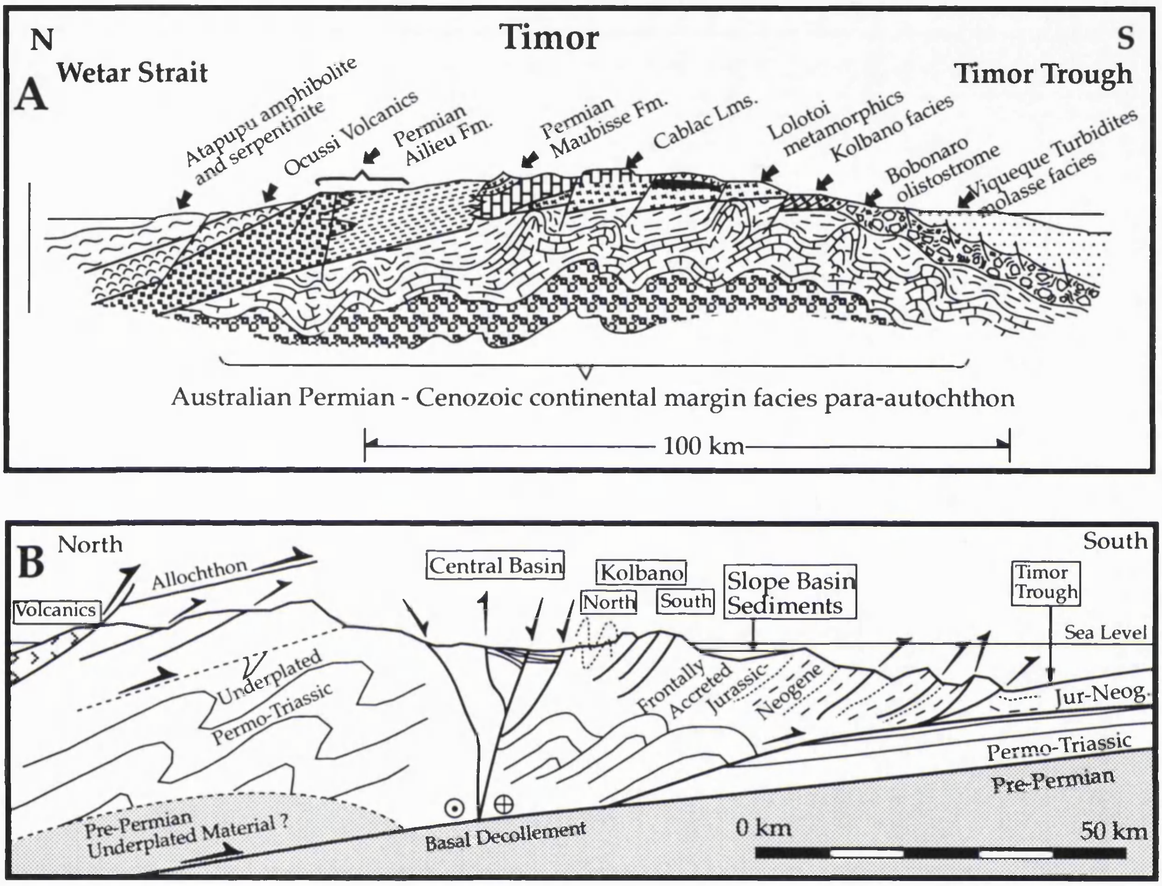
This is the most recent model to have been developed and refined by Charlton (1987); Karig *et al.* (1987) and Charlton *et al.* (1991) (Textfig. 3.7(e)). This model recognises the separation of the Australian margin sediments from a much reduced allochthon (consisting of Mutis/Lolotoi Complex, Palelo and Cablac Limestone formations and the Manamas Volcanic Formation). Left lateral wrench faulting during and post collision is the important element in this model.

Charlton (1989) studied the Kolbano area of southern West Timor and directly correlated it with the Ashmore Block and Sahul Platform. The Upper Triassic Aitutu and Babulu formations can be correlated with the Sahul Group of the Northwest Shelf of Australia, which consists of fluviodeltaic sandstone, shale and micritic carbonate (MacDaniel, 1988). Comparison of the two areas points towards a shared palaeoenvironment from the Jurassic to the Neogene, in which this combined area was the leading edge of the Australian passive margin. Charlton (1989) believed that the Kolbano unit is essentially autochthonous with respect to the Australian margin and that thrusting significantly shortened (by 50%) this unit. The various theories involving either only thrusting or only vertical movements would not explain the resulting structural picture as seen in the Kolbano area. Charlton (1989) concurred with the interpretation of Barber (1979). Barber's model suggests that Australian continental crust was rifted away from the Northwest Shelf during Jurassic seafloor spreading. The fragment was then accreted into the Banda Arc before the Pliocene collision. During the later collision phase the fragment already within the Banda forearc collided with and was thrust onto the margin of the Northwest Shelf as it moved north. Barber's (1979) model was correct if perhaps a little complex in the view of Charlton (1989), who favoured a component of wrench faulting with oblique collision in order to repeat the sequence as seen in southern Timor. The 'Proto-Timor' Plateau and the Scott Plateau were situated on either side of the Kolbano sequence which was deposited between them on thinned Australian crust. The later Pliocene collision (Text-fig. 3.9) was oblique and so material was scraped off and displaced in a left lateral sense. The second collision involved thrusting the Proto-Timor Plateau on to the edge of the Scott Plateau with the Kolbano sequence being imbricated at the foot of the Timor collision complex (Textfig. 3.91, Textfig. 3.92).

A study to constrain the continent-arc collision zone in eastern Indonesia around the island of Timor has been carried out. This involves profiling the upper few hundred kilometres of the crust across the collision zone using gravity and seismic data (earthquake and two BIRPS transects) as well as geological evidence gathered from Timor and the small islands to the east of Timor. A compilation of seismic data shows a high density of earthquake foci at 100-200 km, while at a similar depth in another zone (between 125° and 127° latitude) an absence of seismicity is observed. This seismic gap has been variously interpreted as: detachment of the oceanic portion of the lithosphere from the continental part (Audley-Charles, 1986); a shear zone cutting through the

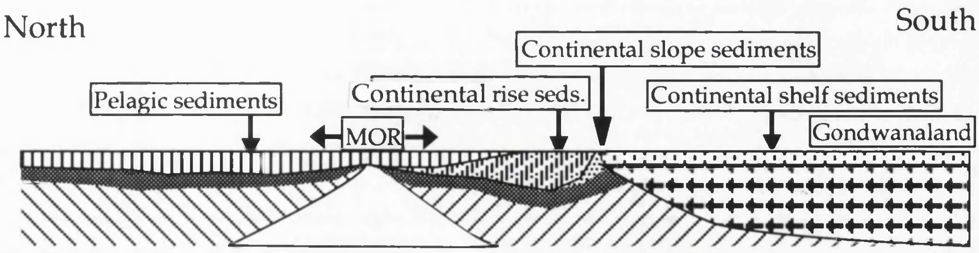


Textfig. 3.9 Diagram illustrating the Pliocene collision of the Australian plate with the proto-Timor Plateau (after Charlton, 1989)

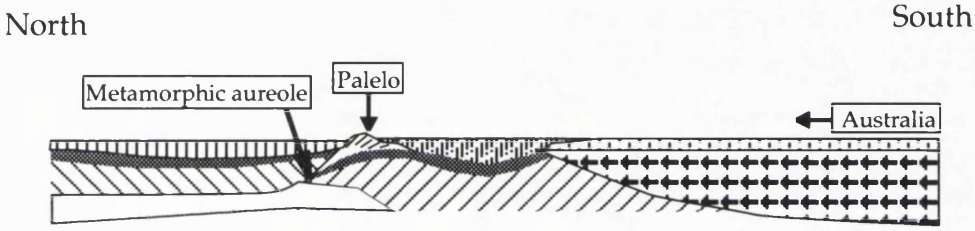


Textfig. 3.9.1 Cross sections through Timor showing structure and lithological units (A after Milsom and Audley-Charles 1986; B after Charlton *et al.*, 1991)

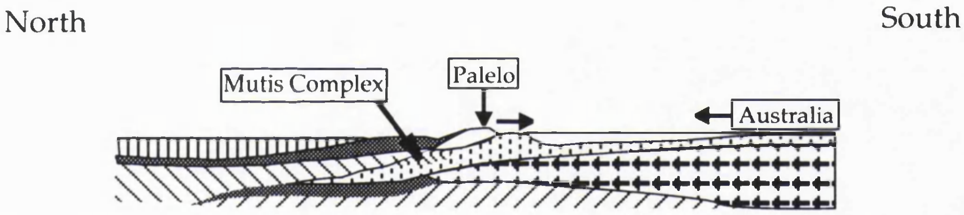
1) Late Jurassic (155 Ma) - Spreading to the north of Gondwanaland (Australia still attached to Gondwanaland).



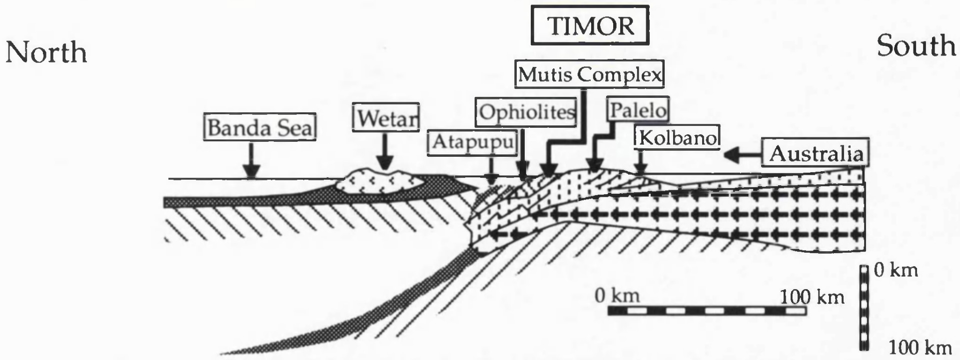
2) Early Cretaceous to Eocene. Spreading dies out, intraoceanic thrusting and opening of Indian Ocean, fragmentation of Gondwanaland.



3) Eocene to Oligocene. Obduction of the Jurassic crust, mylonite overprinting, very low grade metamorphism, Eocene-Oligocene unconformity.



4) Pliocene. Arc-continent collision, obduction of forearc ophiolite.



Textfig. 3.9.2 Possible tectonic development of the Northern Margin of the Australian Continent, Late Jurassic-Pliocene (after Sopaheluwakan, 1990)

lithosphere (Charlton *et al.*, 1991); and as thinning and necking of the lithosphere prior to separation of the the oceanic portion (Richardson, 1991). All of these models would produce isostatic rebound, producing the modern steep topography seen on Timor.

3.6.0 Comparison of Timor and the northwest shelf of Australia

Using the relatively well explored Exmouth and Wallaby plateaux of the southeastIndian Ocean as possible 'close relations' to the Mesozoic sediments found on the Banda Arc islands, it may be demonstrated that the breakup history of the NW continental margin of Australia occurred in several phases during the Permian, Triassic and Jurassic, and that uplift and erosion was often a result of this tectonic activity. The Exmouth Plateau, for example, may be considered to be a proximal, rifted fragment of Gondwana left behind on the Australian coninental slope. According to Teichert (1939), from Late Triassic to Mid Jurassic times the Exmouth Plateau region was a southerly embayment of Tethys. Tensional rifting later led to the breakup of the area and at the time caused NE trending normal faults. At the same period it is believed that the Bonaparte Gulf Basin and the Canning Basin formed as aulacogens. A sedimentary pile of up to 3000m accumulated over the Canning and Carnarvon basins and the Exmouth Plateau, consisting of fluviodeltaic sands and muds. Coevally, trachytic and rhyolitic basalts erupted spreading up to 15km on to the plateau. Later, non-marine coal measures were interbedded with thin marine carbonates during the Early and Mid Jurassic attesting to the paralic nature of the area. Condensed sequences on the plateau are a result of the uplift and low rates of deposition during the period. Emergence and erosion on the northern part of the Exmouth Plateau is marked by ferruginous sediments such as clayey and sandy ironstones. This period of uplift probably coincided with the onset of seafloor spreading. In general the Triassic was a time of gentle subsidence and steady deposition (Exon and Willcox, 1980). Extensive normal faulting in the Late Triassic is related to the tension which led to the later breakup of Gondwana, although both the Exmouth Plateau and Timor exhibit continuous sedimentation into the Early Jurassic (with a minor disturbance observed in the Norian of West Timor by Barkham (1993)).

Greater India moved away from Australia and the Exmouth Plateau in the late Neocomian or Aptian, drastically reducing the amount of clastic supply to the area and gradually opening up the seas to the influence of the Indian Ocean. A major transgression then occurred, possibly coupled with subsidence of the rifted margin resulting in the deposition of shallow marine detrital sediments. From the Santonian onwards the sediments deposited are characteristic of a mature open ocean, as the Exmouth and Wallaby plateaus sank 2-3000m.

A feature of the geological history of these rifted and drifted continental slope fragments is the change from shallow proximal marine, even non-marine sedimentation with sporadic igneous activity, especially in the Triassic and Jurassic sediments to the steadily more quiet, open ocean, pelagic deep water carbonates of the late Jurassic, Cretaceous and younger periods (Textfig. 3.3).

Specific areas on Timor may be directly correlated to the Ashmore Block and Sahul Platform (Charlton 1989). A comparison of the two regions points towards a shared palaeoenvironment from the Jurassic to the Neogene in which the whole area was the leading edge of the Australian passive margin. The collision within the Pliocene telescoped the sediment pile, however, the predeformational facies relationship with Australia may still be observed. Although there has been a high degree of vertical movement which is still occurring today, a significant component of wrench faulting must have taken place (Charlton 1989).

Chapter 4

Geology of the Soe area

4.1.0 Introduction

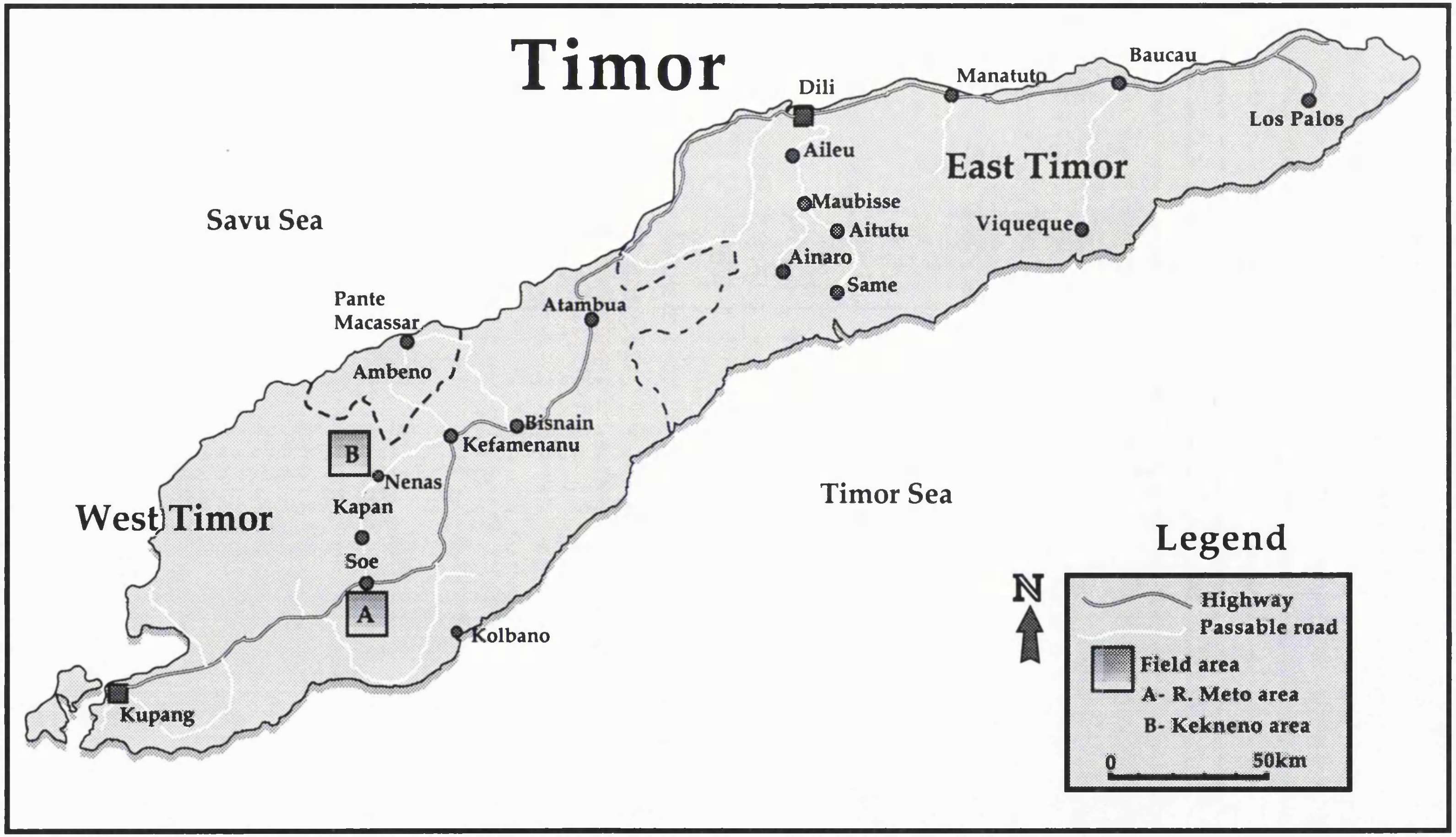
The town of Soe, in central West Timor, lies immediately to the north of the uppermost section of the Noil (River) Meto (Textfig. 4.1). The area consists of steeply incised valleys cutting through a flat Quaternary reef platform to reveal sediments beneath. Only the initial few kilometres south contain measurable outcrop, as further down-stream the topography becomes flatter with only rare outcrops. Barkham (1986) began the investigation of the top eight kilometres of the Noil Meto river section and this chapter is based mainly on his detailed geological observations. The fieldwork of Barkham (1986) also provided a suite of samples from this area to which were added further samples specifically collected by the author in order to obtain a thorough stratigraphic representation of the strata cropping out here. For a detailed sedimentological description of these strata see Barkham (1993).

This study is concerned only with the Aitutu and Wai Luli Formations as recognised in the Noil Meto sections (Textfig. 4.2). These formations range from Late Triassic to Early Jurassic in age and contain rich assemblages of all major microfaunal groups (foraminifera, ostracods, conodonts and nannofossils in addition to radiolarians). Macrofauna is represented by rare ammonoids and more common pelecypods. Outcrops are observed in the river bed of the Noil Meto and its small tributaries to the southwest of the town of Soe, and all are found below the Coralline Limestone (Rosidi *et al.* 1979) which caps the hills locally.

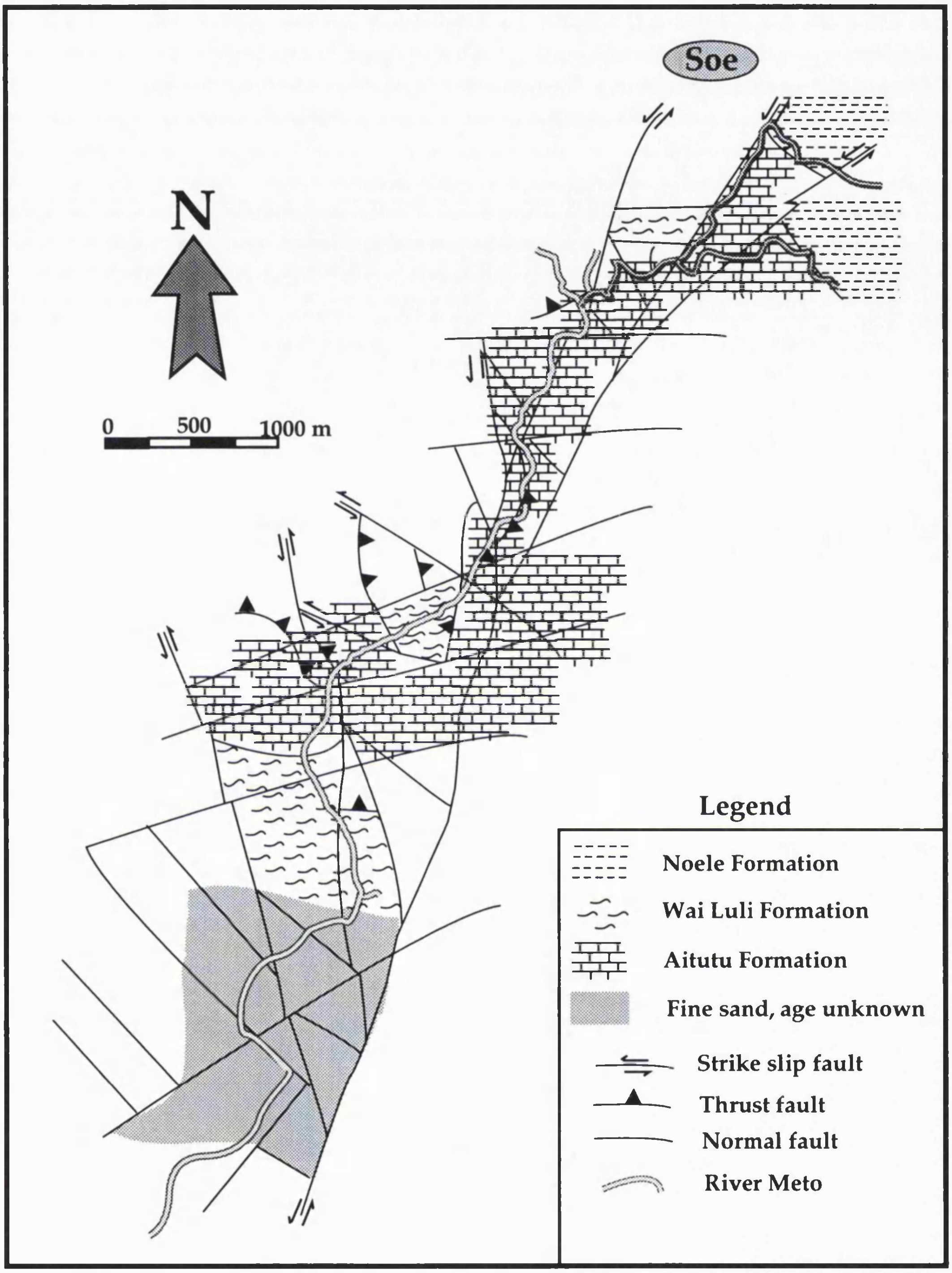
4.2.0 The Aitutu Formation

4.2.1 Introduction

Audley-Charles (1968) introduced the name Aitutu to represent the Upper Triassic sediments of East Timor and, with the addition of a new member (Meto Member, Barkham, 1993), the Aitutu Formation is also observed in West Timor. Previously the



Textfig. 4.1 Location of the River Meto field area in West Timor



Textfig. 4.2 Geology of the River Meto, West Timor
(after Barkham, 1993)

Triassic and Jurassic had been grouped together or misidentified. Van Bemmelen (1949) had described the Triassic and Jurassic of East Timor as mainly shales and sandstones of a flysch facies. Following this, Grunau (1953) reported a radiolarian limestone facies with *Halobia* and *Monotis.* Other studies on the small islands to the east of Timor have indicated the presence of 'radiolarites' which, upon field investigation, are cherts containing no radiolarians, so it is not clear whether Grunau (1953) actually found radiolarians within his limestones or was referring to chert development within or between bedding. Gageonnet and Lemoine (1958) also recognised a Triassic/Jurassic facies containing *Halobia* and consisting of three units, however, these units were grouped together as 'Mesozoic'. To add to the confusion, early workers had, in places, mapped large blocks of Mesozoic sediments within the Bobonaro Scaly Clay as *in situ* Mesozoic.

4.2.2 Type Section

The type section of the Aitutu Formation is found in a large anticline between Maubisse and Same in central East Timor (grid reference 125°40'E, 8° 50'S). Here, as in the Soe area complicated small scale structures frustrate detailed measurement of sections. The base of the formation lies unconformably upon the Permian Cribas Formation. The Tallibelis Member marks the top of the formation in one area. Approximately 80% of the Aitutu Formation consists of calcilutites, 15% is shale and calcareous shales and 5% calcarenites, lumachelles, quartz arenites, radiolarites and highly bituminous rocks (Audley-Charles 1968). Total thickness of the Aitutu in its type section is believed to be in the order of 1000m. The top of the Aitutu Formation is conformably overlain by the Wai Luli Formation with well-bedded, spotted blue grey shales and calcilutites with ammonites at its base. Audley-Charles stated that the Aitutu Formation was Ladinian to Norian in age, with the Wai Luli above being Lower Jurassic (Toarcian, based on ammonites) to possibly Middle Jurassic and occasionally preserved down to the Norian (i.e. not removed in some areas). Audley-Charles (1968) also drew attention to the paucity of the fossil evidence for the Triassic dating and stated that these rocks did not lend themselves readily to stratigraphical study. This view is certainly valid when undertaking stratigraphic work using macrofossil evidence in the field, however, using micropalaeontological techniques a great deal of detailed information may be gained from later research.

4.2.3 Sediments of the Soe area

Barkham (1993) introduced the Meto Member of the Aitutu Formation for the Upper Triassic and Lower Jurassic of the Soe area and suggests that these sediments range from ?Ladinian to late Sinemurian-early Pliensbachian in age. Evidence for the age of the oldest part of the Triassic here is based upon the ammonoid *Auatomites crasseplicatus timorensis* Welter, indicating a late Carnian age, and the pelecypod ?*Daeonella tyrolensis* which ranges from Ladinian to Carnian (Barkham, 1993). Radiolarians recovered in this study have a range from upper Carnian to Pliensbachian/Toarcian. Older strata may indeed be present, however, the structurally complex nature of the sections and annually changing outcrops do not allow sample collection from all suitable horizons. The Aitutu Formation in the River Meto is extensively faulted and folded and contains no marker horizons, resulting in the true stratigraphic thickness of these strata remaining uncertain. Barkham (1993) reported a lack of upper Norian fauna in his samples, however, this study has found many upper Norian radiolarian assemblages. Several explanations may account for observed faunal variations including: sample spacing, not collecting from relevant areas, the use of fossil groups with poor resolution, or differences in the Upper Triassic terminology used (see Chapter 5 on Triassic terminology). There appears to be no evidence at present of an hiatus, although there is, according to Barkham (1993), disruption of the cyclicity or associations in one area.The base of the formation is not seen, however, at the top there appears to be a transitional contact with the Wai Luli Formation above at the first occurrence of the spotted blue marls.

4.3.0 Microfacies analysis

4.3.1 Introduction

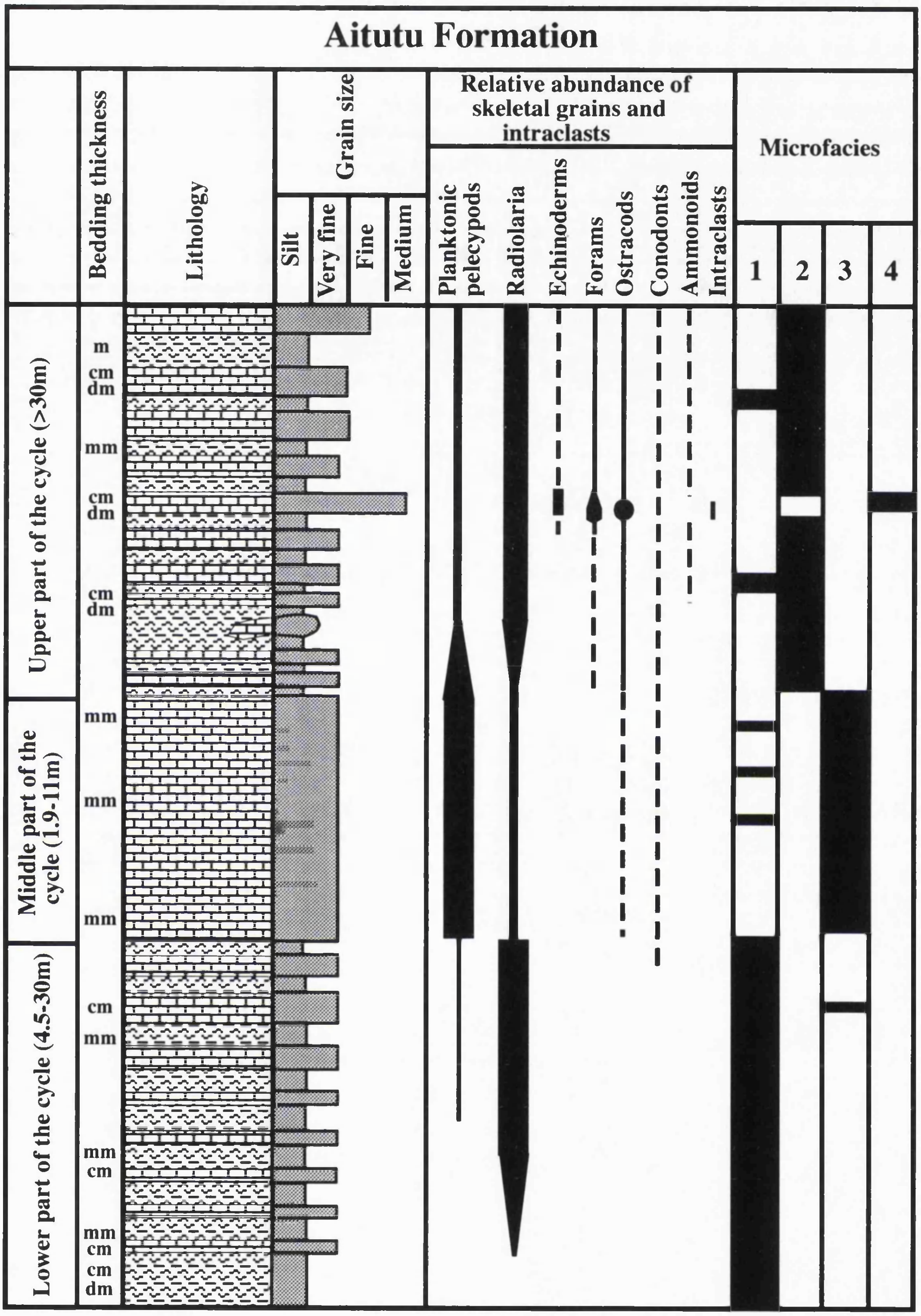
Limestones within the Aitutu Formation are dominantly wackestones and packstones with rare grainstones. Grains mainly consist of radiolaria with, usually, subordinate numbers of forams, ostracods, conodonts, echinoids and pelecypods. The characteristic appearance of the Aitutu Formation in the field is one of a fine grained, light coloured, well-cemented limestone forming couplets with softer and darker coloured marls and shales (Barkham, 1993). Most of the limestones are uniformly white to creamy-white in colour and are approximately 10-20 cm in thickness, although they may be as thick as 60 cm, while the marls and shales are more variable in colour with grey, brown, black, green, maroon and red examples ranging from 1 mm to 2.5 m in thickness. Overall variability is seen both vertically and laterally and may be expressed by localised silicification, pinch and swell structures and bioturbation.

4.3.2 The Meto Member microfacies

Barkham (1993) recognised the following four microfacies types for the Aitutu Formation using Dunham's (1962) classification:
1) Radiolarian wacke/packstone - with up to 80% of the sediment formed by radiolarians infilled with silica and micrite and surrounded by a micritic matrix. Pelecypod shell generally forms less than 5% of the rock, whole valves are concentrated at the top and bottom of the beds.
2) Bioclastic wackestone - bioclasts form less than 50% of the sediment and consist predominently of radiolarians with subordinate amounts of forams, ostracods, conodonts, crinoids and ammonoids in a highly bioturbated micritic matrix. This microfacies type is transitional between types 1 and 3.
3) Pelecypod coquinas - pelecypods predominate and laminate the sediments. Representatives of radiolarian, foram, ostracod and conodont groups occur as a minor percentage of the bioclasts. Where increased bioturbation has taken place, forming a hash, this microfacies may be subdivided, with the increase in infaunal activity resulting in little lamination or silicification (see Barkham, 1993).
4) Graded bioclastic limestone - comprising of 25-30% pelecypod valves and 10% radiolarians with subordinate forams, ostracods, echinoids and intraclasts cemented in a blocky spar. The pelecypod valves filled with micrite contain smaller forms of radiolarians than in the calcite cement.

4.3.3 Lithological description

The combinations of the facies associations are cyclical in nature (see Text-fig. 4.3 for schematic diagram of cycle). The base of the cycle begins with thinly bedded (cm) planar limestones interbedded with thicker calcareous shales and less frequent marls. Limestone, sedimentologically, as a proportion of the sediment, increases upwards. Most of these limestones belong to microfacies group 1, changing to group 2 where bioturbation has taken place, reflecting a change in the bottom oxygenation. These rhythms consist of creamy to grey coloured limestones and generally dark brown to dark grey shales in a sequence of between 4.5->30m in thickness.



Textfig. 4.3 Sedimentological classification of the Aitutu Formation (schematic) (after Barkham, 1993)

The middle part of the cycle has a sharp transition separating it from the lower layered part, and consists of finely laminated planar limestones. Laminations are formed by parallel pelecypod valves which dominate this part of the sequence. Pelagic fauna is generally much reduced here. Microfacies group 3 forms the vast majority of this part of the cycle, and in the field is relatively easily identified as the valves form a yellow seam concentrated along the middle of a bed, which is often also the site for silicification. A range of 1.9-11m has been measured for this part of the rhythm.

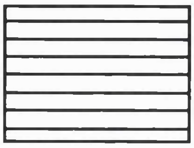
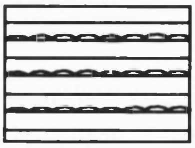
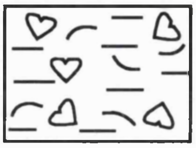
A much more gradational transition marks the change from middle to upper part of the cycle. Interbedded marls increase, initially forming beds only a few millimetres thick and later increasing to 2.5m in thickness. Limestones are generally nodular, bioturbated and, for the most part, consist of microfacies group 2, with less frequent examples of microfacies 1. Pelecypod coquinas (microfacies group 3), however, are commonly impersistent by their very nature as a shell bank. Shale horizons occur, although they tend not to be as well-developed as the marls. A relatively rich assemblage of benthos, in the form of ostracods, forams and crinoids indicates that much more favourable bottom water conditions were established resulting in increased bioturbation. The bedding forms of the limestones vary from nodular to planar, this taking place through a sequence up to 10m or from one bed to the next. The nodular limestones are generally homogeneous internally and have associated chert infilled burrows (*Calianassa).* Planar limestones are less homogenised and contain tracks of *Planolites* and *Palaeophycus* and *Thalassinoides* burrows on the underside of the beds, indicating that aerobic conditions were restricted to just below the sediment/water interface. One thicker bed has been identified by Barkham (1993) containing laminations (parallel and cross) and is placed within microfacies group 4. A thickness of 35m or more has been suggested for this upper part of the cycle.

Barkham (*pers. comm.* 1993) indicated that there are several of these three part cycles. Faulting in the River Meto sections may have resulted in repetition of some parts of these cycles, however, palaeontological evidence suggests age differences between the same parts of the overall cycle in different sections. Faulting, therefore, cannot account for all of the repetition observed. The boundary between the Aitutu and Wăi Luli formations occurs at the position of the base of the blue spotted marls and is thought to be Sinemurian in age.

4.3.4 Sedimentological and palaeoecological interpretation

For the lowest part of the cycle, Barkham (1993) interpreted the sedimentologically structureless lithologies as being deposited in a low energy environment, below wave base, as part of a distal turbidity flow. Shales here indicate reduced oxygen conditions by their colour (red and green). Black shales are rich in organic matter which, during deposition, may induce low oxygen conditions, limiting the amount of epifaunal activity. A significant epifauna and infauna would have led to rapid destruction of the organic laminations (Hallam 1987). The sharp nature of the bases of the limestones appears to be as a result of event deposition, such as turbidity flow or storm currents, which were strong enough to winnow the sediment leaving periodic shelly coquinas.

The presence of planktonic faunal assemblages supports the sedimentological analysis in confirming the relatively deep nature of the marine conditions, as no shallow water benthic forms are observed. Calcareous nannofossils are present (*Prinsiosphaera triassica, Eoconusphaera zlambachensis,* and *Thoracosphaera geometrica*) and these represent the oldest known nannofossil groups and indicate open marine conditions. Absence of benthic faunas also indicates low oxygen conditions on the substrate. The saturation of oxygen in sea water is approximately 6-8.5 ml/l.. Benthic metazoans, such as ostracods and decapods may exist in concentrations down to around 1ml/l. Below this figure faunas are reduced in number, diversity and size, resulting commonly in monospecific assemblages. Waters with concentrations of less than 0.5ml/l. dissolved oxygen can be regarded as effectively anoxic (Demaison and Moore, 1980). Deposit feeders become rare in lower oxygen levels quickly followed by suspension feeders. Limestones also show evidence of low oxygen conditions by their lack of biotubation. Common macrobenthos in the form of pterioid bivalves such as *Daeonella, Halobia* and *Monotis* are believed, from their facies associations, to be relatively deep water dwellers (Hallam, 1987). These bivalves crowd bedding planes between unfossiliferous strata. This form of colonisation is characteristic of an opportunistic species triggered by small, and often ephemeral, alleviation of anoxic conditions. Any further increase in oxygen levels results in more epifaunal and infaunal activity, and therefore, burrowing and lamination destruction (Text-fig. 4.4). The shales found here have not been deposited in monotonous sequences, and are regularly punctuated by the deposition of turbiditic limestones, which attests to tectonic and sedimentological instability during deposition.

	 **Barren laminite**	 **Shelly laminite**	 **Shelly Shale**	 **Shelly Mudstone**
Petrology	Well-developed kerogen-clay/calcite laminae	Well-developed kerogen-clay/calcite laminae	Moderate to poorly developed, often discontinuous organic laminae. Low to moderate bioturbation	No organic laminae. Bioturbation has destroyed original sedimentary layering
Palaeontology	No benthic fauna	Low diversity, high density epibenthic fauna, confined to discreet bedding planes	Low to moderate diversity, moderate density epi-and shallow endobenthic fauna, +/- uniformily dispersed through sediment	Moderate to high diversity, moderate density epi-, shallow and deep endobenthic fauna including trace fossils

Textfig. 4.4 Petrological classification of organic-rich layered rocks (after Hallam, 1987)

The middle part of the cycle consists of in-situ shell banks which exhibit little movement or bioturbation. Low energy conditions prevailed with variations in either the supply of carbonate mud or input of the pelecypod bivalves resulting in the concentration of the valves in places.

A sparse benthic fauna coupled with a lack of bioturbation suggests low oxygen conditions on the substrate. Plankton, in the form of radiolarians, is much reduced which probably indicates shallow water. Only heavily silicified, poorly preserved spherical forms are present, and these are almost impossible to identify, indicating preservational, rather than palaeoenvironmental reasons for the lack of radiolaria.

The upper part of the cycle is characterised by marls and limestones which appear to grade into one another. Turbidity currents were still active, but occurred with less frequency as indicated by the rarity of flute clasts, ripple laminations and normal grading. A general lack of coarse sedimentation (conglomerates) or indicators of instability coupled with small amount of shallow water material suggest a low energy distal outer ramp setting (Barkham, 1993). Occasionally thicker beds were deposited containing a more varied fauna, with a generally coarser, grain-supported microfacies. This would indicate sourcing from a different, shallower area. Barkham (1993) suggested that an upward increase in the amount of carbonate material was possibly the result of: 1) siliciclastic material by-passing the area, 2) drowning of the source area, 3) imposition of a barrier between the siliciclastic source area and the area of carbonate accumulation, due either to tectonic activity or sea level changes. A general shallowing-upwards sequence is postulated by Barkham (1993), and the sedimentology indicates a substrate above or close to the storm wave base or a more proximal position.

Palaeontologically, the upper part of the cycle sees the return of abundant radiolarians, forams, and ostracods. The uniserial nodosariid forams, which become common, are mid-shelf dwellers during the Late Triassic and abundant ostracods indicate favourable substrate conditions. Bioturbation also increases as a result of the abundant benthos. (For a list of the faunas present in each part of the cycle see Textfig. 4.5).

	Fossil group	Faunal content	Stage
Upper part of the cycle	**Ammonites:**	*Anatropites crasseplicatus timorensis*	Carnian
	Pelecypods:	*Halobia superba*	Carnian
	Crinoids:	*Entrochus ternio*	Sevat
	Conodonts:	*Gondolella polygnathoformis*, *Epigondolella* cf. *primitia*, *Gondolella nodosa*, *Gondolella spatulate*, *Gondolella* cf. *steinbergensis*	Lac and Sevat
	Forams:	*Pseudonodosaria vulgaria multicameratia*, *Frondicularia rhaetica*, *Dentalina* sp., *Nodosaria* sp., *Pseudobolivina torniata* Laginidae	Rhaetian-Liassic
	Ostracods:	*Ptychobairdia kuepperi*, *Anisobairdia gibba*, *A*, *barkhami*, *A. ? fastigata*, *Triadohealdia alexandri*, *T. pertruncata*, *T. opisotruncata*, *Torohealdia amphicrassa*, *T. opisthocostata*	Sevat
	Nannofossils:	*Prinsiosphaera triassica*, *Crucirhabdus primulus*, *Crepidolithus crassus*, *Parhabdolithus liassicus liassicus*, *P. liassicu distinctus*, *Biscutum novum.*	Rhaetian-Sinemurian
Middle part of the cycle	**Pelecypods:**	*Halobia zittel*, *?Daeonella tyrolensis*, *Monotis salinaria salinaria*	Carnian (Julian)
	Conodonts:	*Epigondolella* sp. indet.	Norian
		Note- This part of the cycle is dominated by pelecypods with greatly reduced microfauna.	
Lower part of the cycle	**Pelecypods:**	*Halobia superba*	Carnian
	Conodonts:	*Gondolella polygnathiformis*, *G. hallstadtensis*, *Epigondolella* sp. indet.	Norian (Lac)
	Radiolarians:	The following genera were identified and reported by Barkham (1993): *Capnodoce*, *Capnuchosphaera*, *Canoptum*, *Crucella*, *Betraccium*, *Acanthocircus*, *Paronaella*, *Syringocapsa*, *Orbiculiforma Sarla*, *Xiphotheca*, *Pseudoheliodiscus*	Carnian-Norian

Textfig. 4.5 Faunal content of the cycles in the Aitutu Formation

4.4.0 The Wai Luli Formation

4.4.1 Introduction

Audley-Charles (1968) was the first to identify the Jurassic from the 'autochthonous Mesozoic' of Grunau (1953) and Gageonnet and Lemoine (1958). The Wai Luli Formation was described from the valley of the Wai Luli near the village of Aitutu (grid reference 125° 40' E, 8° 50' S) in eastern Timor. As with the Aitutu Formation, the true stratigraphic thickness of this formation cannot be measured because of the structurally complex nature of both the type section and the River Meto area, although Audley-Charles (1968) estimated a thickness of approximately 800m. The lithology in the type section is described as basal spotted blue-grey marls and calcilutites with ammonites, above which micaceous shales, thin bedded calilutites and quartz arenites occur and at the top of the section coarse conglomerates are found. As a result of the soft nature of the base of the Wai Luli Formation it is only exposed in a few locations along the Meto River section. Audley-Charles (1968) placed the boundary between the Aitutu Formation and the Wai Luli formation at the level of the lowest spotted blue-grey marl occurrence. Darker spots here are thought to represent the burrowing structures of *Planolites.* There are no noticeable lithological changes across the Triassic/Jurassic boundary zone, indeed, it is not known whether the boundary is preserved here or not. Audley-Charles stated that the Aitutu was entirely Triassic (Ladinian-Norian) in age, however, Barkham (1993) has extended the Aitutu into the Early Jurassic. In the type area in eastern Timor, conglomerates appear towards the top of the section, where clasts are mainly of Aitutu limestones and were regarded by Audley-Charles (1968) as rudites. The radiolarians in the Lower Jurassic part of the Aitutu have had their silica replaced by calcite, making identification more difficult.

4.4.2 Microfacies analysis

4.4.3 Introduction

The Wai Luli Formation is dominated by blue/grey spotted, usually laminated, bioturbated marls varying in thickness from 3cm-3m or more. In the field, these marls may be distinguished from those of the Aitutu Formation as they are not colour banded. These marls are also chalky in nature because, for the first time, calcareous nannofossils are present possibly in rock-forming amounts. White radiolarian wacke/packstones are interbedded with the marls.

4.4.4 The Wai Luli microfacies

Barkham (1993) (Textfig. 4.6) recognised the two following microfacies groups using Dunham's (1962) classification:

1) radiolarian wacke/packstones - of mainly spumellarian radiolarians in a bioturbated, carbonate mud matrix containing organic matter. Radiolarians are replaced by calcite, and so prove difficult to extract.

2) carbonate mudstone - carbonate muds with inclusions of dark, organic-rich muds.

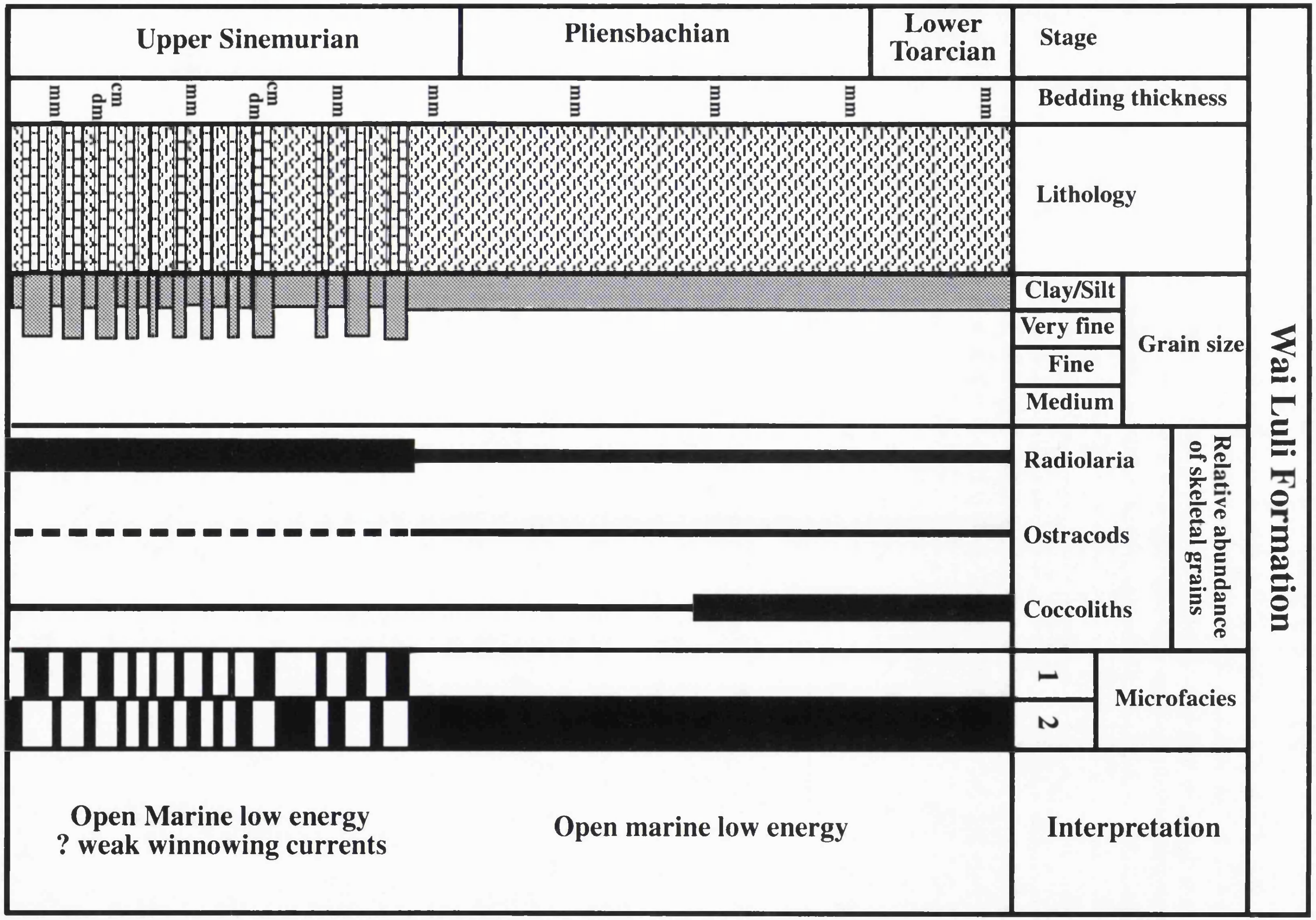
4.4.5 Sedimentological and palaeoecological interpretation.

A general lack of sedimentary structures indicates a low energy, marine environment below storm wave base and largely isolated from turbidite activity.

Palaeontologically, radiolarians again dominate the preserved plankton, although, their accumulation rates do appear to be cyclical, which suggests periodic increases in nutrient supply to the upper part of the water column. Calcareous nannofossils (*Prinsiosphaera, Eoconusphaera,* and *Thoracosphaera*) were present in the Aitutu Formation, and represent the oldest known representatives of this group. It is not until the Lower Jurassic (in this case the Wai Luli Formation) that calcareous nannofossils, in the form of coccoliths and schizospheres, possibly contribute to the matrix of these sediments. The replacement of the silica forming the tests of the radiolarians by calcite suggests that released silica escaped the sediment before the later stages of diagenesis occurred (Barkham, 1993), implying that burial of the plankton was slow or that silica-rich fluids were flushed out of the sediments. This formation has a gradational boundary with the Aitutu Formation below. The age of the Wai Luli Formation studied in this project is considered to be from late Sinemurian to early Toarcian. The top of the Wai Luli Formation is not seen in the river Meto sections.

4.4.5.1 Discussion

Barkham (1993) divided the Wai Luli Formation into two microfacies groups: 1) Radiolarian wacke/packston and 2) Carbonate mudstone. No cyclicity is observed and a general lack of sedimentary structures indicates a low energy marine environment below storm wave base. Palaeontologically, calcareous nannofossils become significant and occur in rock forming quantities. Radiolarian and nannofossil age data combined give an age of Pliensbachian to Toarcian (Early Jurassic) for the Wai Luli Formation sampled in the River Meto sections of West Timor.



Textfig. 4.6 Sedimentological classification of the Wai Luli Formation (after Barkham, 1993)

4.5.0 Overview of the Upper Triassic-Lower Jurassic West Timor.

4.5.1 Introduction

No major sedimentological break is seen from the Carnian (Late Triassic) to the Pliensbachian (Early Jurassic) in the River Meto area. Barkham (1993) also studied sections in the Bisnain and Laktutus areas, where he found facies variations. Eight such variations were recognised in the Aitutu Formation as seen in the Meto Member (Barkham, 1993).

4.5.2 Comparison with the Kekneno area

4.5.3 The Niof Formation

Cook (1986) and Bird (1987) both examined the Upper Triassic of the Kekneno area to the northwest of Soe, in West Timor. The Niof Formation was defined by Cook (1986) and, based on palaeontolological evidence (sparse ammonoids and bivalves)was thought to be Anisian to Ladinian (Cook and Bird, 1991). Field measurements indicate a thickness of 630m for the entire formation, which is divided into five members (two principal) in Cook (1986). A certain amount of confusion was caused by Bird (1987) who assigned the Pipasur Limestone Member to the overlying Babulu Formation. Phosphatic nodules distinguish the Numfuamolo Member and indicate deposition on a submarine high subject to upwelling marine currents (Jenkyns, 1978). Sedimentation of the Numfuamolo Member gives way to the red, green and grey shales of the Niplelo Member above. This moderately deep water environment contained no benthos and a sparse planktonic assemblage including radiolaria.

4.5.4 The Babulu Formation

The Babulu Formation, a series of well-bedded sandstones, shales and subordinate limestones, was introduced by Giani (1971). A clear stratigraphic contact may be observed with the Niof Formation below, although this is diachronous. An age of Carnian to Norian, with sediments possibly as old as Ladinian, is based on sparse bivalve, ammonoid and palynological data (Cook, 1986; Bird, 1987). The Babulu

Formation is seen to conformably overlie the Niof Formation (Bird, 1987) with diachronous contacts. Bird (1987) assumed that the Aitutu Formation diachronously overlies the Babulu Formation. This assumption was not confirmed by Barkham (1993) as the bases of both the Aitutu and Babulu formations are thought to be of similar age (Ladinian). Considerable lateral variation is exhibited and results in the existence of a number of members (Pipasur Limestones, Lapunuf Sandstones, Tasenip Limestones, Noil Naito Shales). Intraformational breccias up to 20m in thickness are present and appear similar to those found in East Timor by Audley-Charles (1968). Limestones here seem to have been deposited as part of turbidity currents resulting in skeletal packstones as seen in the Soe area. In some places only carbonate sedimentation has taken place, in others siliciclastics only are found, and intimate mixing of the two types occurs elsewhere (Bird and Cook, 1991). The Aitutu and the Babulu Formations appear to be closely related because of the similarities in the carbonate portion of both formations (Pipasur Limestone Member in the Babulu Formation). Skeletal wackestones containing pelecypod bivalves and radiolaria are present in both units, but the conglomerates, which characterise parts of the Babulu Formation are absent in the river Meto sections. The Aitutu Formation, in general, lacks the siliciclastic part of the Babulu Formation and therefore is either well away from the deltaic sedimentation produced in the Kekneno area or is shielded from the siliciclastic sedimentation. Occasionally Babulu type sands were deposited from turbidity currents in the River Meto sections during the Triassic suggesting that a deltaic fan periodically swept over the carbonate ramp on which the Aitutu Formation was deposited (Barkham, 1993). An occurrence of siliciclastic, carbonate and mixed provenance turbidites, reflects the probable variation in the depositional regime in the shelf area which provided the detritus (Bird and Cook, 1991).

The wide variety of facies types, changing both vertically and laterally, makes an accurate palaeogeographic reconstruction difficult. Measured palaeoflow directions suggest the possible evolution of a small fault-controlled basin (Bird and Cook, 1991), with several small turbidite fans feeding sandy material directly into the basin and with finer sedimentation away from such fans. The amount of carbonate input increases when siliciclastic input decreases and vice versa. Cook (1986) undertook a detailed study of the petrology and heavy mineral composition of the Upper Triassic sediments of the Kekneno area and compared these to similar age sediments observed in wells offshore to the south of Timor and on the northwest shelf of Australia. It was found that with a few exceptions the sandstones were generally less mature in the Kekneno area and had a distinctly different heavy mineral content. Only sediments from the Sahul

Shoals, the closest well to Timor were similar to those of the Kekneno area and may well have shared a common provenance.

Sandstones are present in the River Meto sections, however, the relationship of these sands to the carbonates was not studied and is therefore not clearly understood, although their presence indicates a relationship with the sediments of the Kekneno area.

4.5.5 The Tallibelis Member

The Tallibelis member is a distinct series of argillaceous beds found at the base of the Aitutu Formation according to Audley-Charles (1968), however, Audley-Charles moved the Tallibelis Member to the top of the Aitutu (*pers. comm.* in Tobing (1988)). Lithologically, the Tallibelis Member consists of purple and dark blue, well-bedded mudstones with mixed shelly beds and pyrite found throughout. Barkham (1993) stated that the Meto Member and Tallibelis Member are mutually exclusive. The Tallibelis Member is thought to represents a period of siliciclastic sedimentation with poor planktonic fossil presence.

4.5.6 The Meto Member

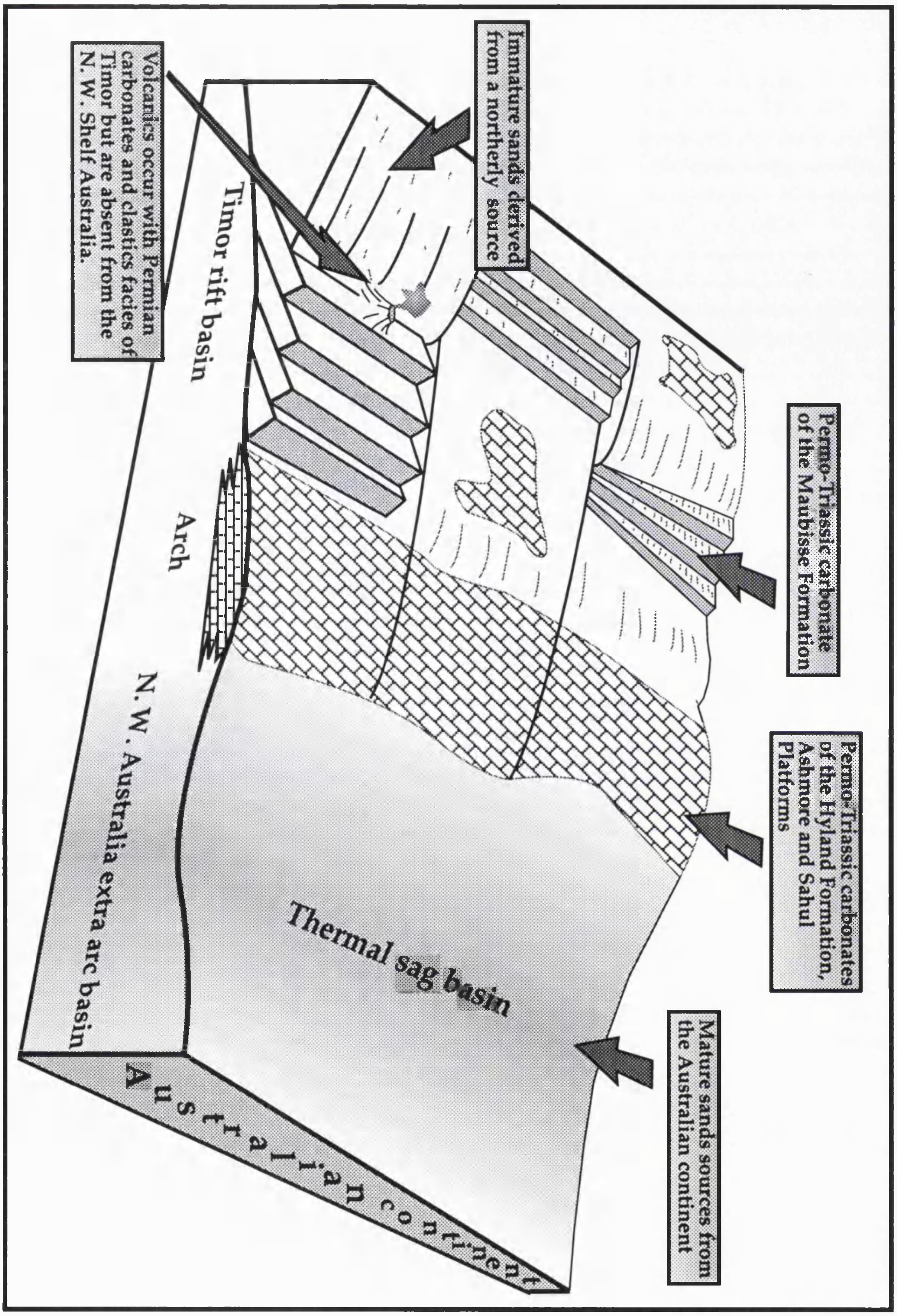
The Meto Member was introduced and described in detail by Barkham (1993), in which he also concluded that the contact with the Cribas Formation was probably a fault contact and not an unconformable contact as postulated by Audley-Charles (1968). The Aitutu Formation is also believed to interdigitate with the Niof Formation. The Meto Member is a cyclic sedimentary sequence with the oldest sediments cropping out in the Bisnain and Soe areas, but not in the Laktutus area (Barkham, 1993). No high energy or instability features have been recognised in the Meto Member, leading to the conclusion that a low energy ramp environment was the site of deposition. Depths of between 50m and 200m for the Meto Member are suggested by benthic foram and trace fossil evidence. Barkham (1993) suggested that the limestone, shale and marl alternations, coupled with the areas of bioturbation and non-bioturbation, were a result of sea level changes. Low stands which increase deltaic input into restricted basins lowered the salinity and therefore sealed bottom waters resulting in bottom water anoxia. The turbidite-deposited limestones were sourced from a deep and/or low energy setting (Barkham, 1993). He also recognised a change in sedimentation during the Norian in all three studied areas indicating a basin wide event, possibly faulting or transgression resulting in the reworking of shallow facies. This event was succeeded by uniform carbonate sedimentation in the Lower Jurassic. The Soe area appears to be more distal, as the Laktutus area has intraformational conglomerates typical of a proximal setting situated further to the east.

4.5.7 Palaeoenvironmental setting

Lithologies and palaeontological content of the Late Triassic sediments found in Timor indicate a restricted marginal sea (Niof Formation), dominated by fine siliciclastics. Bird and Cook (1991) suggested that a small fault-controlled basin with several small turbidite fans had developed. Faulting or transgression affected the sedimentation patterns, causing either increased carbonate input (following drowning or transgression) and siliciclastic dominance following uplift or regression. Away from the main deltaic sources a ramp was formed where carbonates accumulated (Aitutu Formation) and over which the deltaics of the Babulu Formation were occasionally deposited (Text-fig.4.7). A further period of extension is indicated by Norian faulting and uplift (Barkham, 1993). The evidence for instability and uplift is recorded on the basin margins where intraformational conglomerates were deposited (Laktutus area and in eastern Timor). More stable environments were established in the Early Jurassic with generally fine grained sedimentation blanketing the area.

4.6.0 Comparison of Timor and the northwest shelf of Australia

The geology of the Exmouth and Wallaby plateaux was investigated by von Stackelberg *et al.* (1980) and generally they encountered a more nearshore setting for the Triassic and Jurassic than found in Timor. The Exmouth Plateau was part of a southerly embayment of Tethys which suffered extension and developed northeast-trending faults (von Stackelberg *et al.*, 1980). Thick deposits of fluviodeltaic and paralic sediments were produced (~3000m) in the Late Triassic. Late Triassic and Early Jurassic trachytic and rhyolitic lavas were extruded subaerially or in shallow water on the northern parts of the Wallaby Plateau, and preceeded the Mid Jurassic breakup of the Exmouth Plateau. During the Early Jurassic thick non-marine clastics and coals were laid down over the Canning and Carnarvon Basins, while further north thick marine carbonates attest to the late Sinemurian-Pliensbachian marine transgression in the Westralian Trough (Quilty, 1980). Throughout the rifting phase (Late Triassic-Mid Jurassic) the



Textfig. 4.7 Tectonosedimentary model for the Permo-Triassic of Timor and the N.W. Shelf of Australia (after Barkham, 1993)

region remained near sea level, with Triassic sedimentation and subsidence rates at about 50-100m per million years (von Stackelberg *et al.*, 1980).

ODP Leg 122 drilled four sites on the Wombat Plateau, further west, and recovered Late Triassic nannofossils. Sites 759, 760, 761 and 764 were sampled and found to contain *Prinsiosphaera triassica, Thoracosphaera wombatensis, T. geometrica, Eoconusphaera zlambachensis, Crucirhabdus primulus, C. minutus* and *Archaeozygodiscus koessenensis.* The assemblages indicate a Norian to Rhaetian age and correspond, in part, to assemblages recovered in the present study. Palaeoenvironmentally the Late Triassic assemblages of the Wombat Plateau are very similar in composition to those observed in the Alpine region (Bralower *et al.*, 1991). Using modern analogues *Prinsiosphaera* is believed to inhabit marine continental margin settings which, in this case, may have been harsh, which may account for the lack of faunal variation observed. However, this phenomenon may equally be a result of evolutionary causes. Triassic sediments containing the nannofossils interfinger with lagoonal and reefal facies and therefore the environment was probably that of a fore-reef.

Cook (1986) carried out a detailed study of several boreholes drilled during oil exploration on the northwwest shelf of Australia. Triassic strata were retrieved in 17 of the boreholes and these show a variation of environments ranging from fluvial to marginal-marine to marine. In Early Triassic times a landmass lay to the east of the area and seas to the west. This landmass was partially flooded by a transgression in the Mid Triassic and later seas regressed in the Late Triassic. Sediments from the northwest shelf were sourced from a separate area to those found in the Kekneno area and Sahul Shoals.

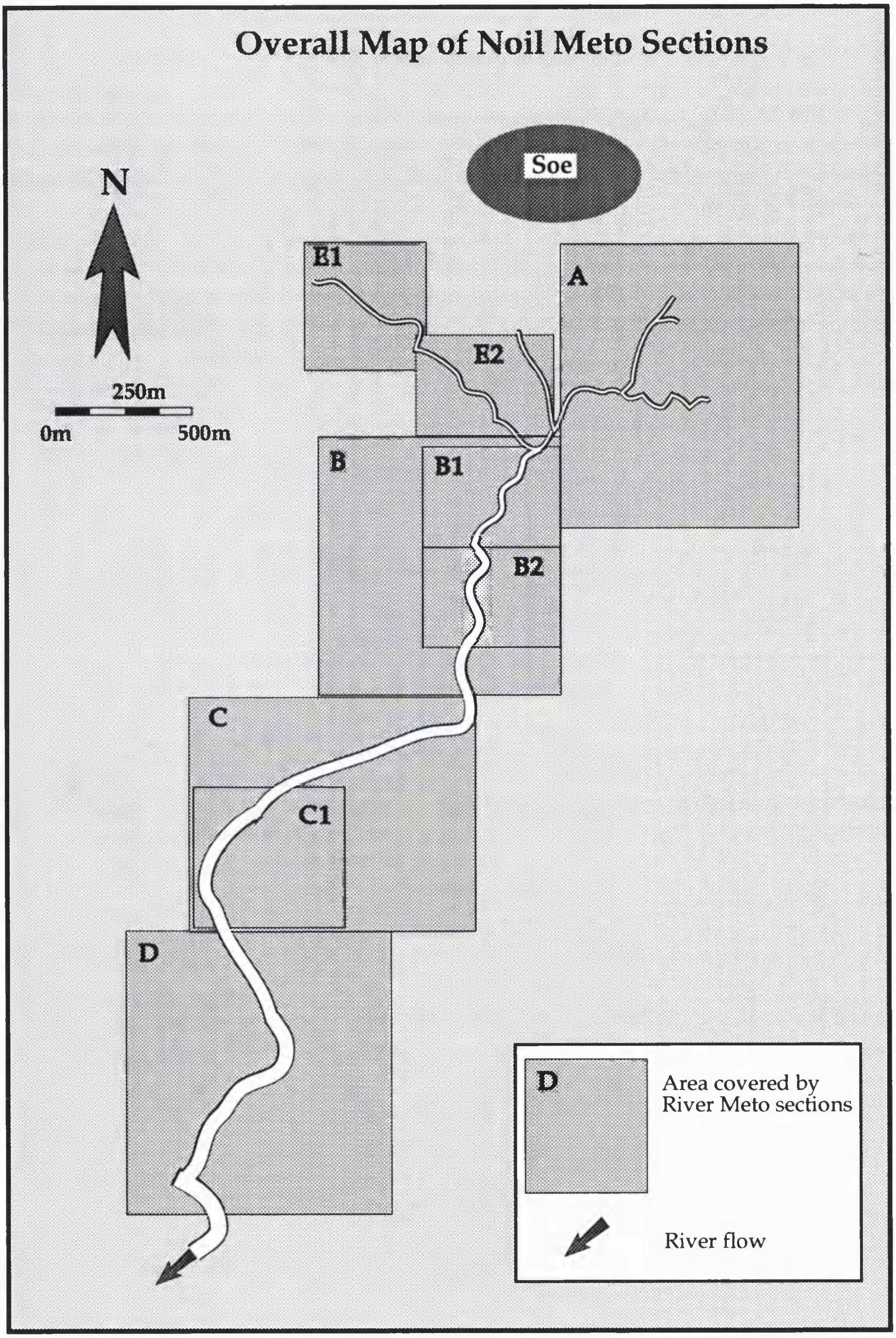
4.7.0 River Meto logged sections

Two sets of samples were taken along the River Meto and its tributaries. The first set was taken by Barkham (1986) as part of a sedimentological and structural study of the Permo-Triassic of West Timor. These samples were taken over a wide area and were mainly spot samples with a brief description of the section from which they were taken. Only locational data is given for this first set of samples.

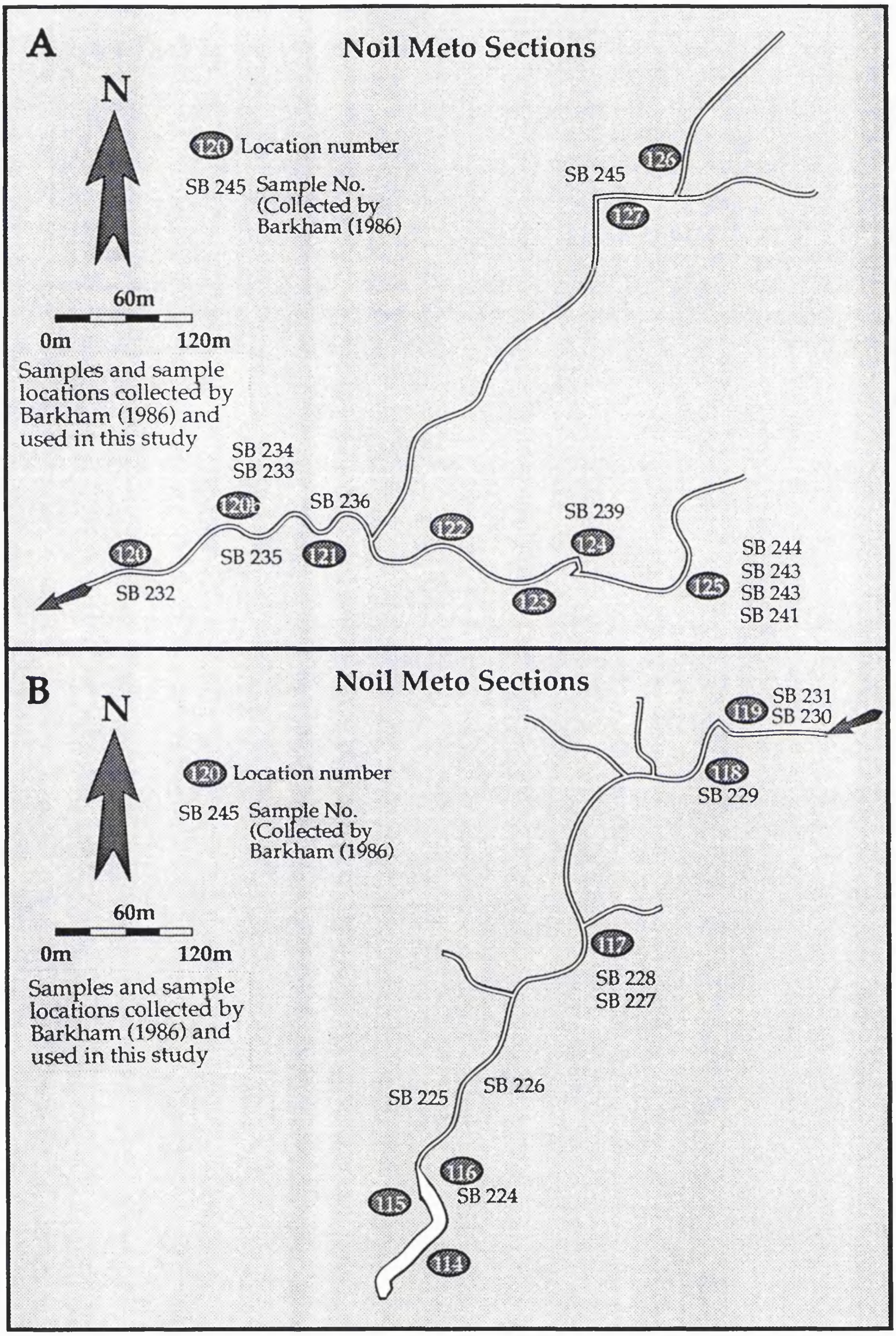
A second sample set was taken by the author in 1990 as part of the fieldwork undertaken for this study. Micropalaeontological sampling techniques were employed with sections logged and several samples taken at each locality in order to maximise the chance of collecting abundant and diverse faunal assemblages. Each sample and location is plotted on a map of the River Meto and cross referenced with a diagram of the section encountered with relative positions of each sample recorded. It is hoped that this method will offer the clearest way of indicating local lithology with location. The six maps and five section are illustrated below.

4.8.0 Section photographs

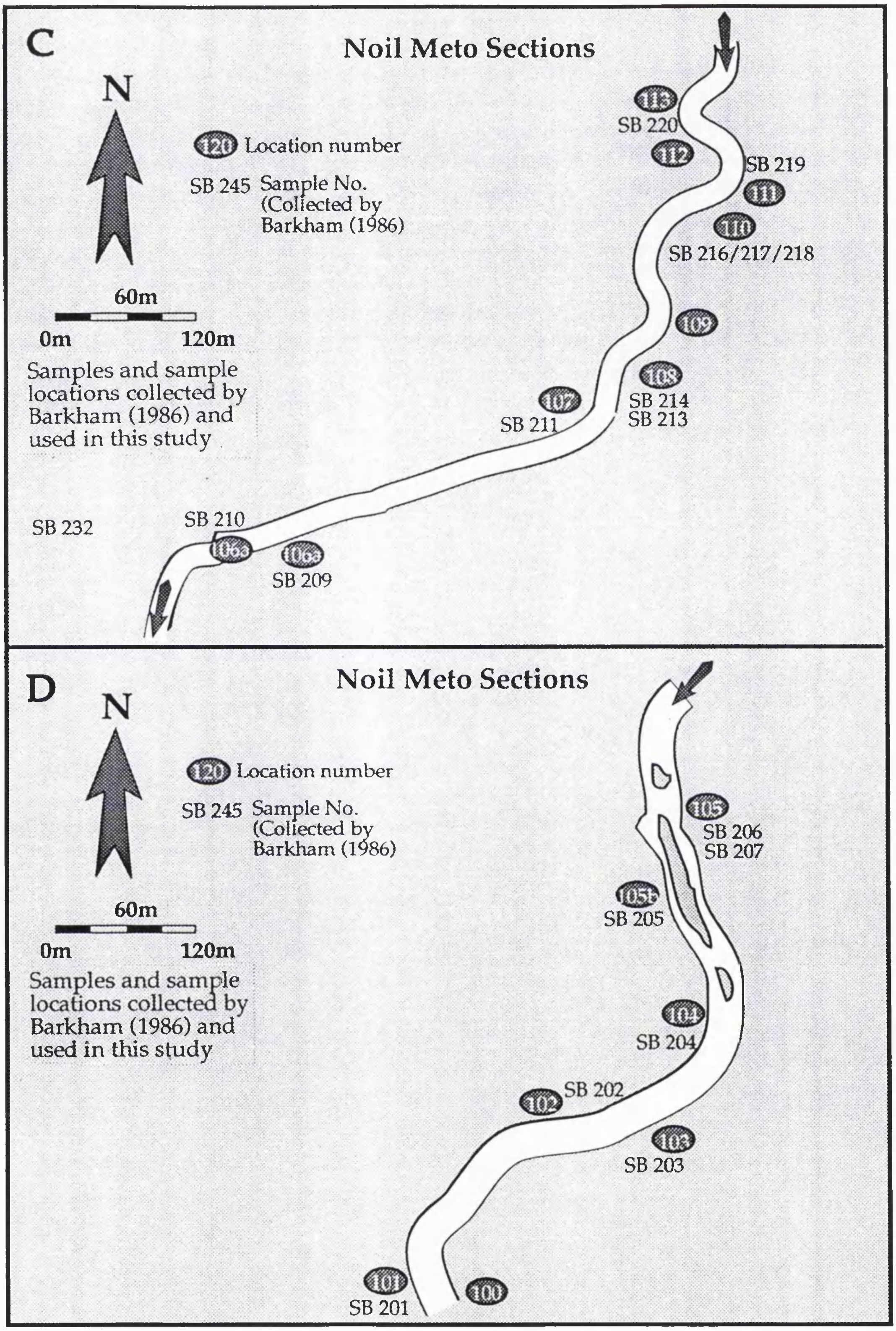
Photographs of all the sections visited and sampled during this study were taken. A selection of some typical sections encountered along the River Meto follow the logged sections below. Lithologies from the Aitutu and Wai Luli formations are shown.



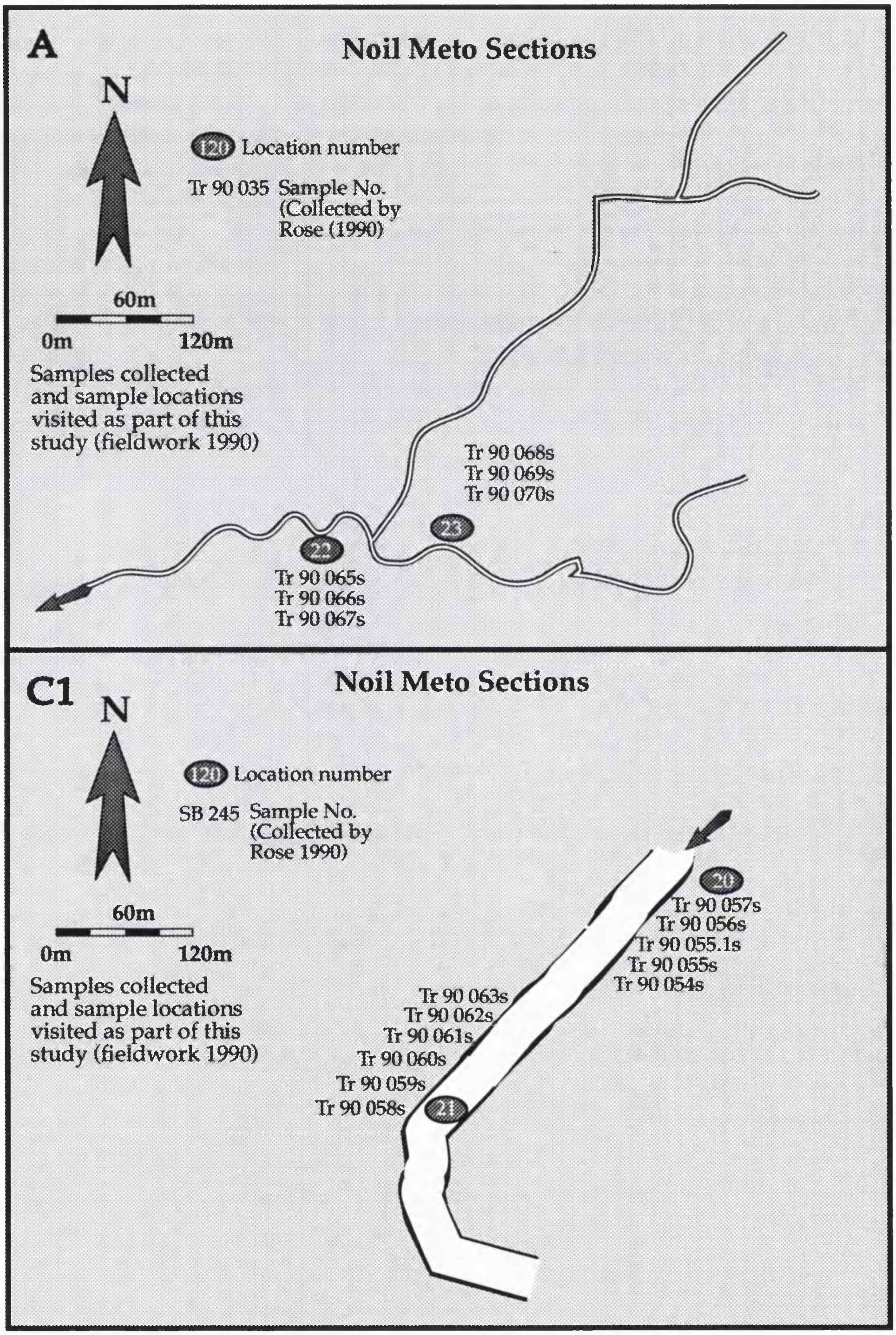
Textfig. 4.8.1 Map of River Meto sections, West Timor.



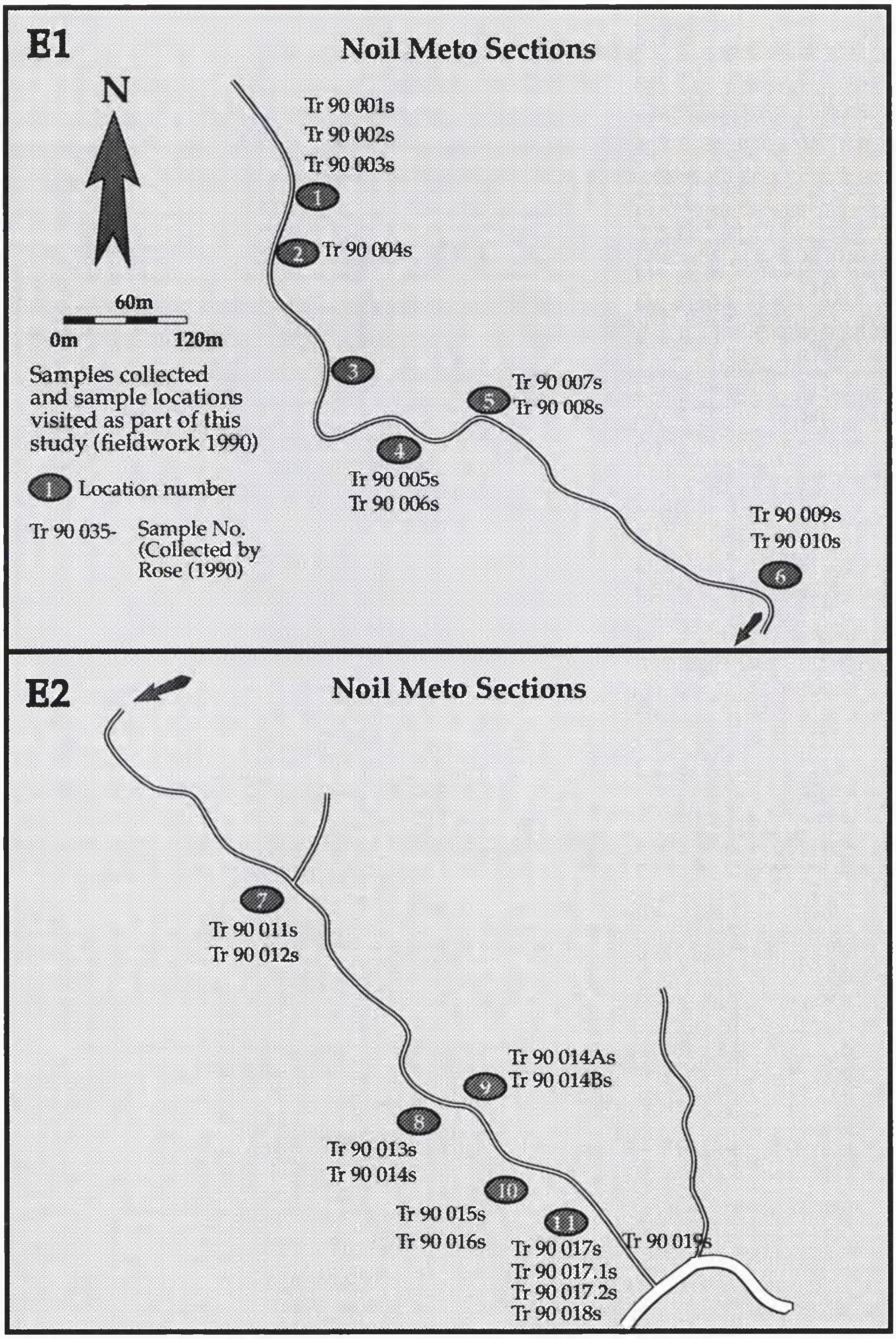
Textfig. 4.8.2 River Meto sections (A, B) locations of Barkham (1986)



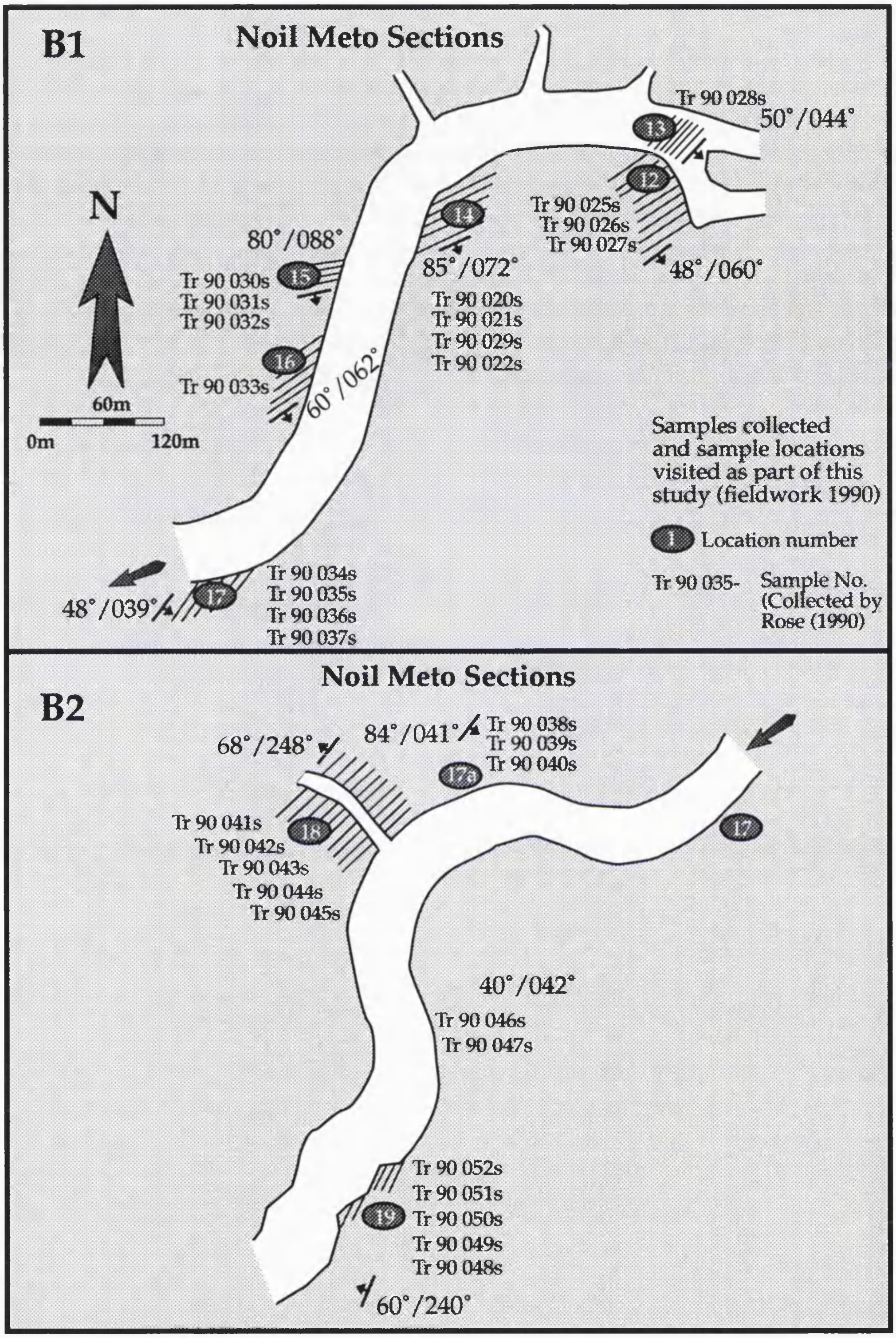
Textfig. 4.8.3 River Meto sections (C, D) locations of Barkham (1986)



Textfig. 4.8.4 Map showing sample locations (A, C1) collected by Rose 1990 on the River Meto sections Soe, West Timor



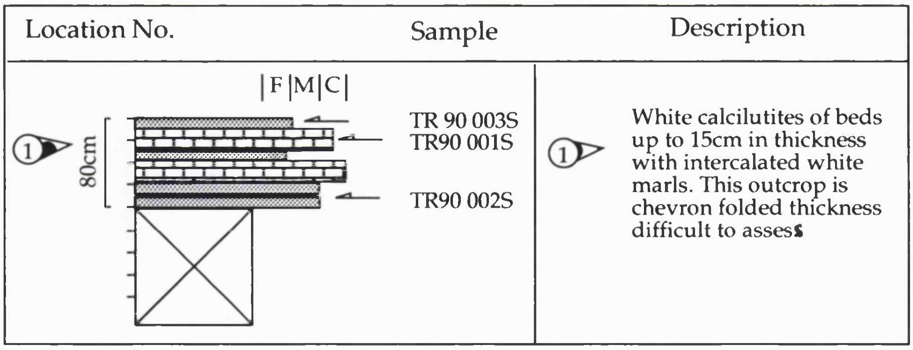
Textfig. 4.8.5 Map showing sample locations (E1, E2) collected by Rose 1990 on the River Meto sections Soe, West Timor



Textfig. 4.8.6 Map showing sample locations (B1, B2) collected by Rose 1990 on the River Meto sections Soe, West Timor

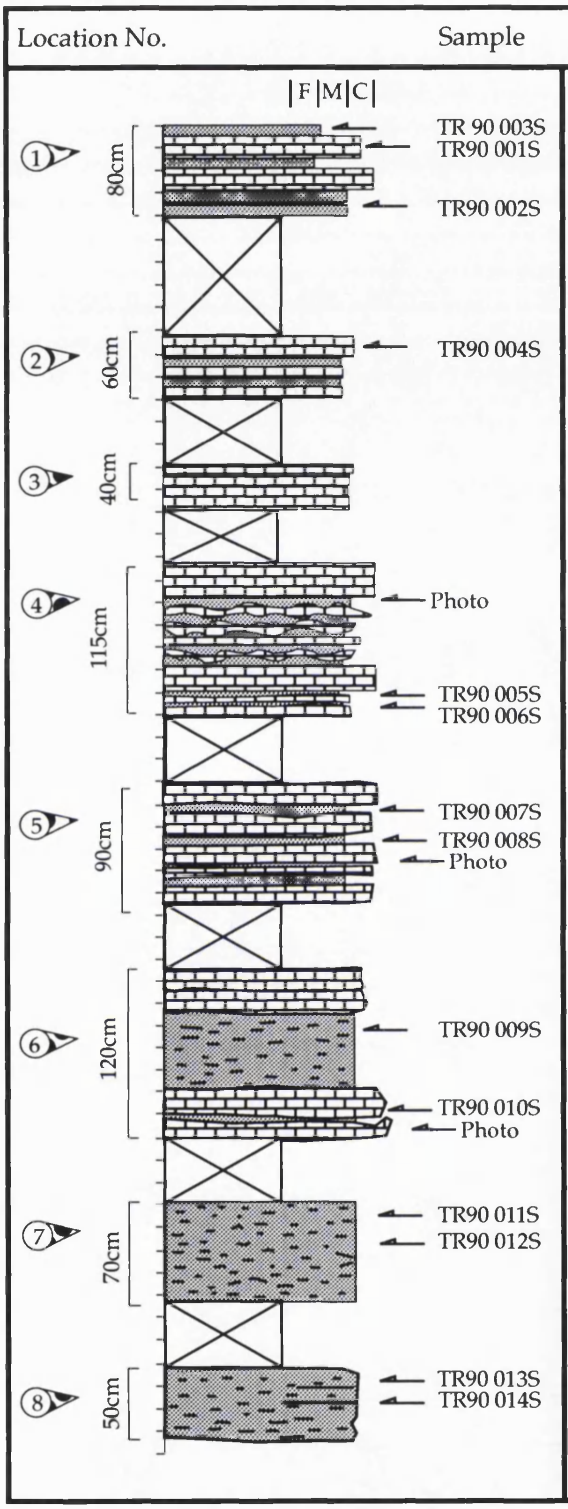
The following diagrams (log sections 1-5) consist of data taken directly from fieldnotes recorded during this study. The sections are from the River Meto and its tributaries found to the south of the town of Soe in central West Timor. All sections are measured and described with sample horizons clearly marked. Each section is given a location number and illustrated on a map of the area. A legend for the symbols used is given below together with an example of a complete diagram and description of a typical section encountered in this region of Timor.

①▶	Section location number
◀ TR 90 003S	Sample number
|F|M|C|	Sediment particle size
▦	Calcilutite beds exhibiting pinch and swell structures
▦	Undeformed calcilutites
▒	Marls
☒	No exposure



White calcilutites of beds up to 15cm in thickness with intercalated white marls. This outcrop is chevron folded thickness difficult to assess

Textfig. 4.9.1 Legend for lithological logs of the River Meto sections (collected by Rose in 1990).



Description

① White calcilutites of beds up to 15cm in thickness with intercalated white marls. This outcrop is chevron folded and thickness difficult to assess.

② Powdery yellow/white calcilutites more competent rocks have slid on intercalated marls.

③ Evenly bedded calcilutites

④ Beds of grey/white calcilutites up to 15cm in thickness. Faulting is perpendicular to bedding. Evidence of slickensides and pinch and swell structures.

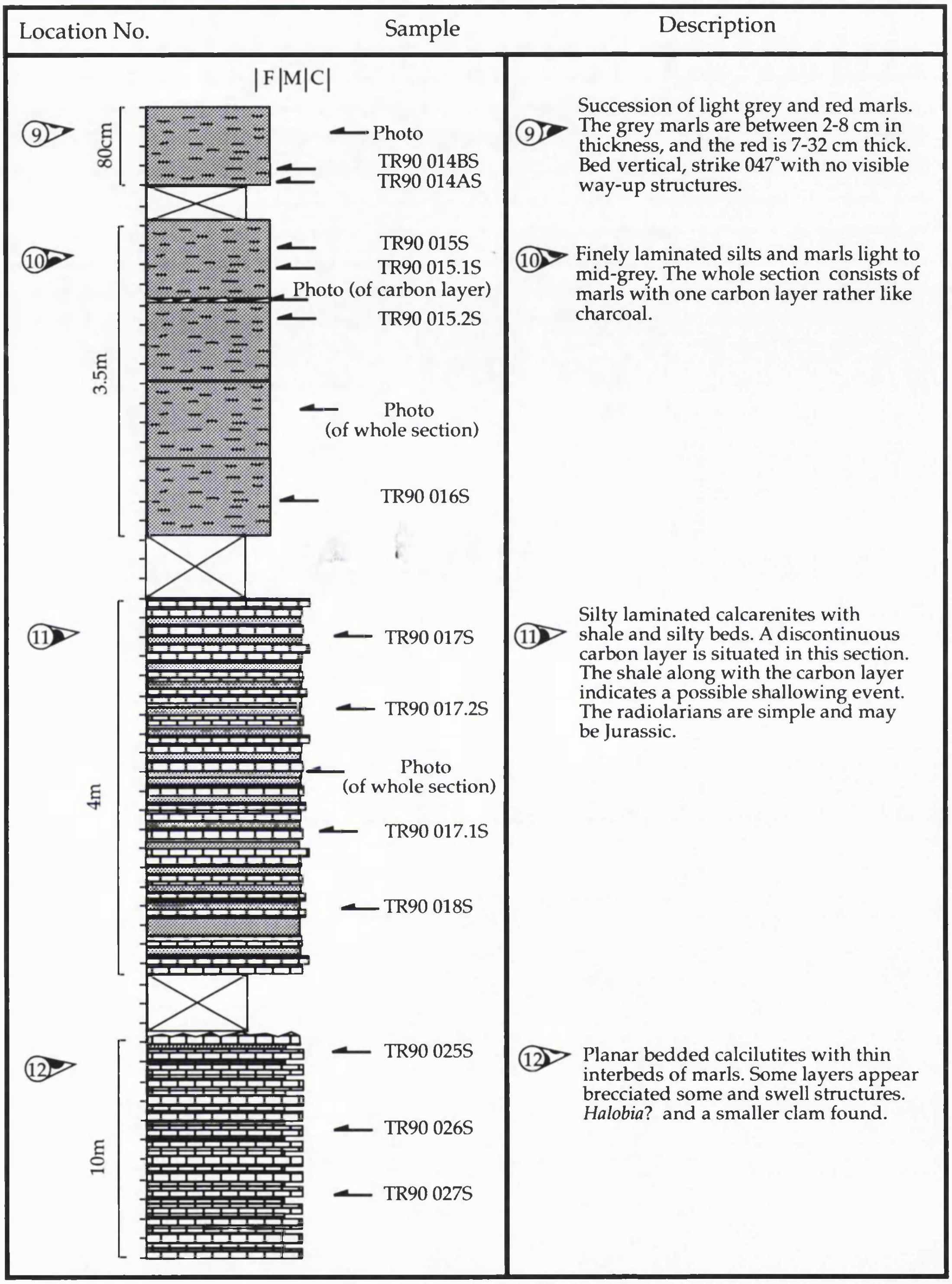
⑤ White calcilutites interbedded with thin marls. Calcilutites up to 23cm in thickness. Weakly calcareous pink clays (1-2cm) developed above the thicker beds more strongly calcareous white marls appear immediately below (1.5cm). These finer sediments are in contact with the deformed undersides of the thicker beds forming sole structures.

⑥ Poorly bedded massive limestones which fine downwards to marls.

⑦ A series of marls no other lithologies, poor outcrop may not be *in situ*. Dip Approx. 10'/015'

⑧ Grey and red, friable claystones finely laminated exhibiting blocky weathering.

Textfig. 4.9.2 Lithological logs (1) of the River Meto sections (collected by Rose in 1990).



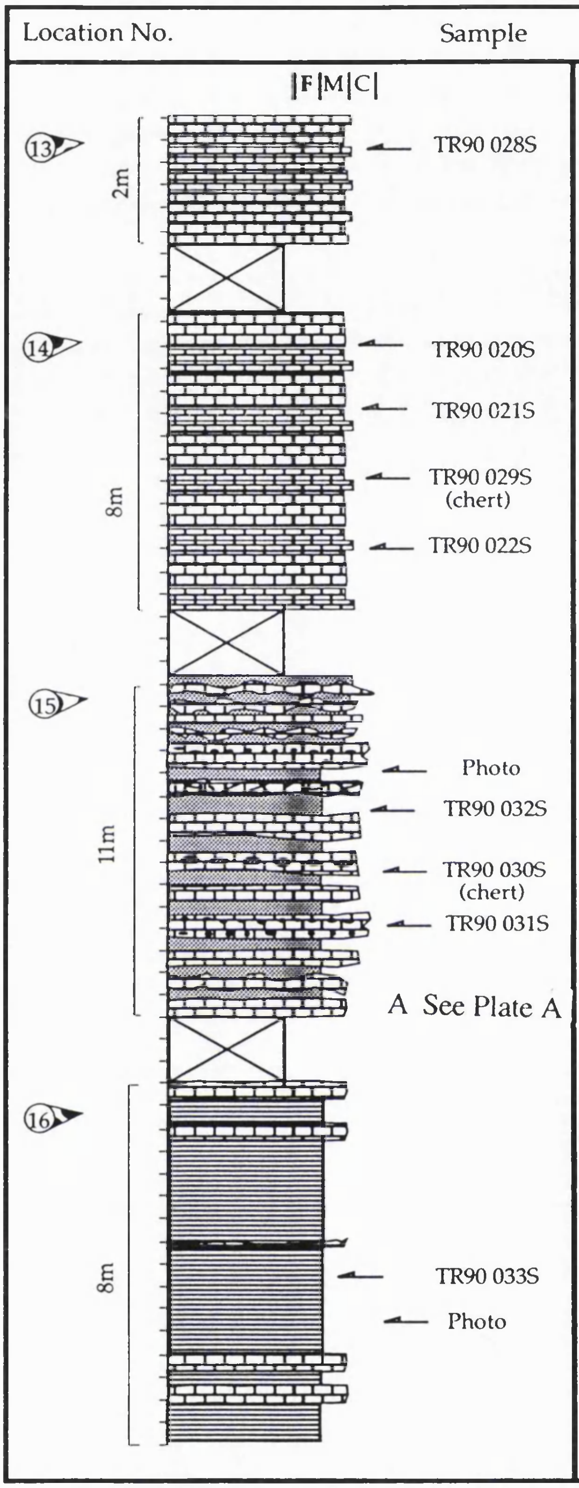
9 Succession of light grey and red marls. The grey marls are between 2-8 cm in thickness, and the red is 7-32 cm thick. Bed vertical, strike 047°with no visible way-up structures.

10 Finely laminated silts and marls light to mid-grey. The whole section consists of marls with one carbon layer rather like charcoal.

11 Silty laminated calcarenites with shale and silty beds. A discontinuous carbon layer is situated in this section. The shale along with the carbon layer indicates a possible shallowing event. The radiolarians are simple and may be Jurassic.

12 Planar bedded calcilutites with thin interbeds of marls. Some layers appear brecciated some and swell structures. *Halobia*? and a smaller clam found.

Textfig. 4.9.3 Lithological logs (2) of the River Meto sections (collected by Rose in 1990).



Description

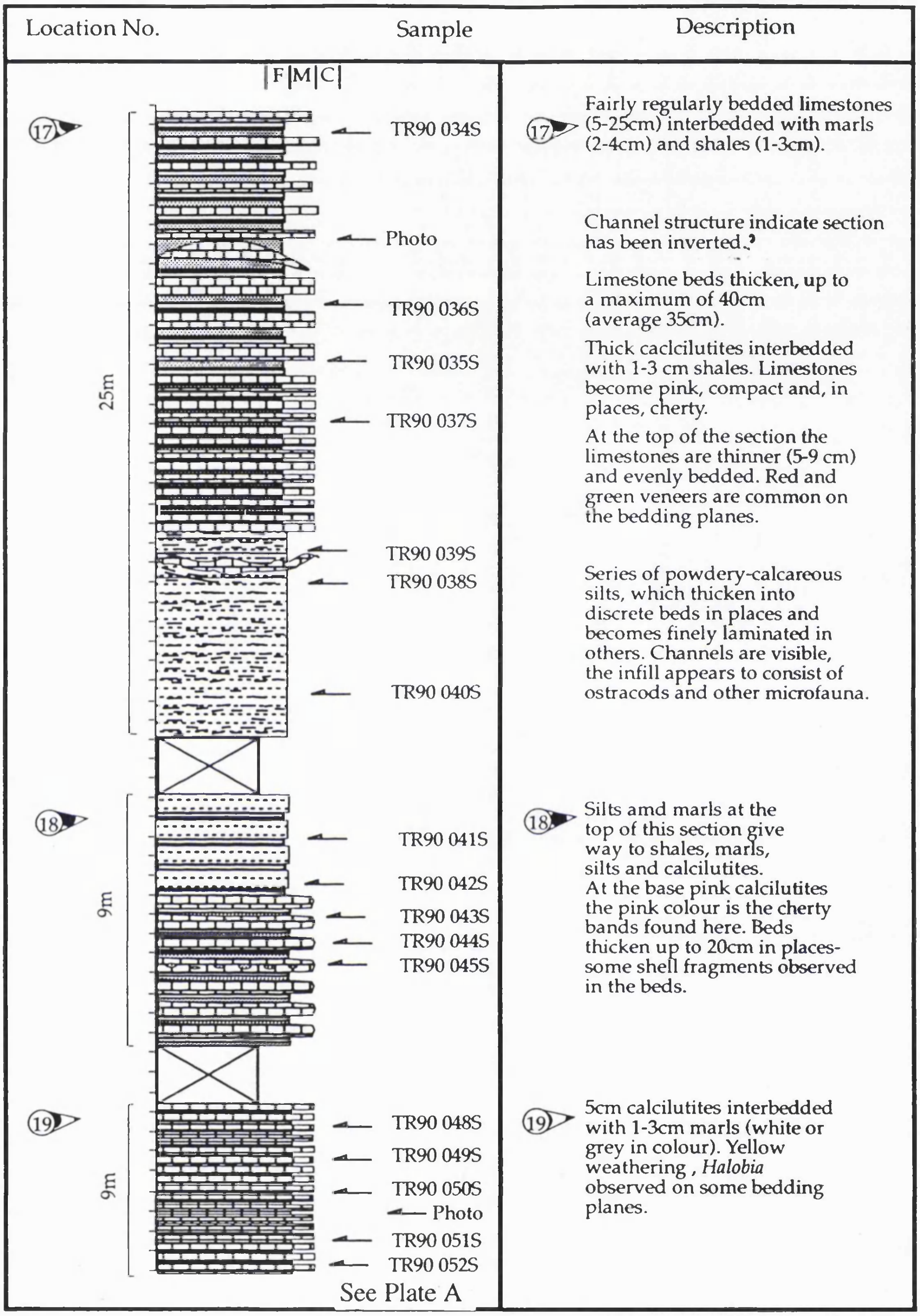
⑬ Planar bedded calcilutites (50/044).

⑭ Regularly bedded white calcilutites which appear to be brecciated and cherty in places (85'/072').

⑮ Beds often brecciated and cherty in places. Bedding becomes less planar with extreme pinch and swell structures with the marls in between being severely squeezed. Thicker beds are up to 40cm in thickness and are coarse packstones at the base with shelly fragments, finer material in the centre of the bed (forams, rads, etc.) and coarse on top. Black and grey cherts in places (80'/088').

⑯ Beds of calcilutites 5-20cm in thickness, much more shale (quiet environment with low oxygen?) is present up - to 2.5m thick between the limestone beds.

Textfig. 4.9.4 Lithological logs (3) of the River Meto sections (collected by Rose in 1990).



(17) Fairly regularly bedded limestones (5-25cm) interbedded with marls (2-4cm) and shales (1-3cm).

Channel structure indicate section has been inverted.?

Limestone beds thicken, up to a maximum of 40cm (average 35cm).

Thick caclcilutites interbedded with 1-3 cm shales. Limestones become pink, compact and, in places, cherty.

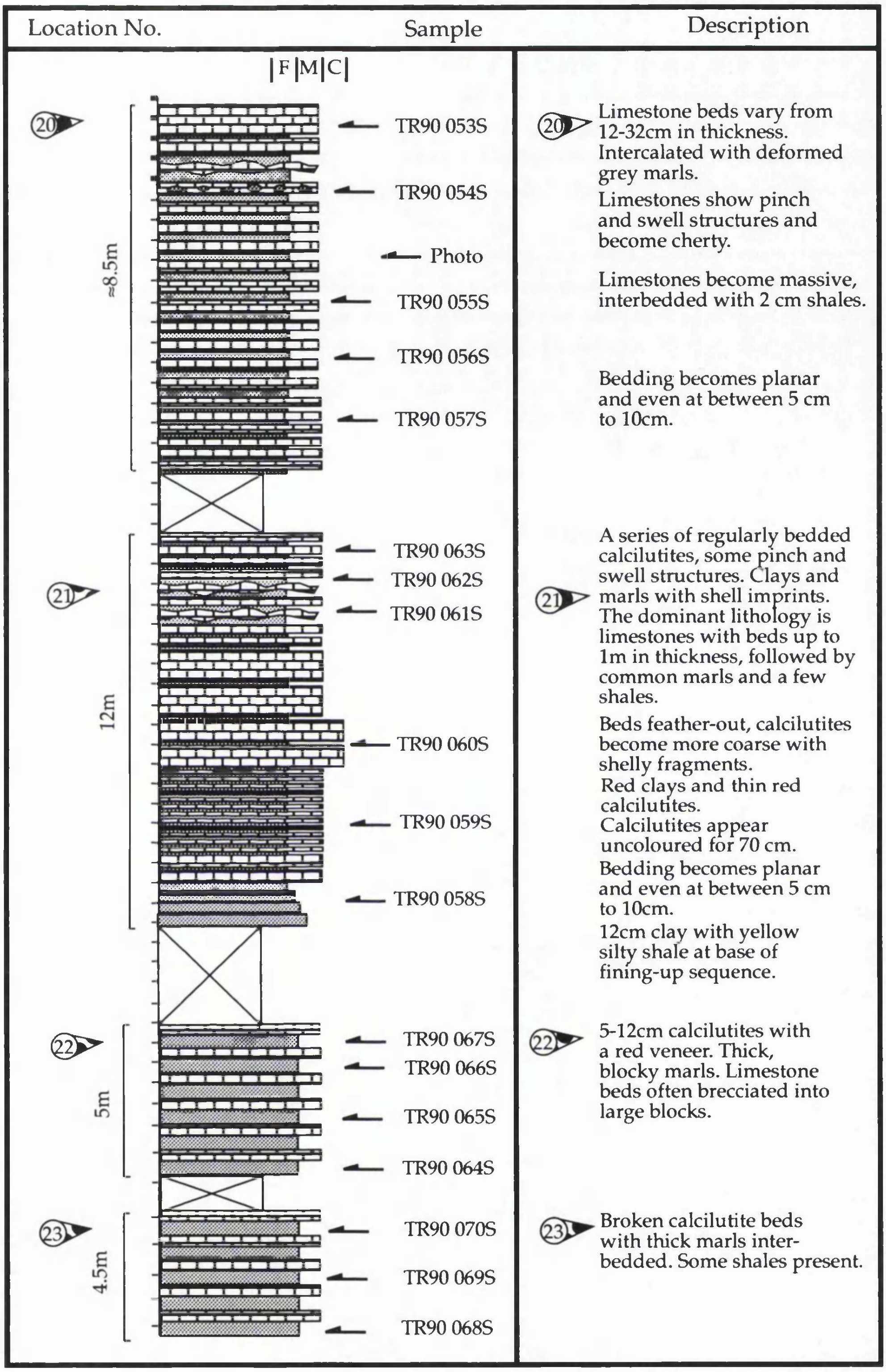
At the top of the section the limestones are thinner (5-9 cm) and evenly bedded. Red and green veneers are common on the bedding planes.

Series of powdery-calcareous silts, which thicken into discrete beds in places and becomes finely laminated in others. Channels are visible, the infill appears to consist of ostracods and other microfauna.

(18) Silts amd marls at the top of this section give way to shales, marls, silts and calcilutites. At the base pink calcilutites the pink colour is the cherty bands found here. Beds thicken up to 20cm in places- some shell fragments observed in the beds.

(19) 5cm calcilutites interbedded with 1-3cm marls (white or grey in colour). Yellow weathering , *Halobia* observed on some bedding planes.

Textfig. 4.9.5 Lithological logs (4) of the River Meto sections (collected by Rose in 1990).



20 Limestone beds vary from 12-32cm in thickness. Intercalated with deformed grey marls.

Limestones show pinch and swell structures and become cherty.

Limestones become massive, interbedded with 2 cm shales.

Bedding becomes planar and even at between 5 cm to 10cm.

21 A series of regularly bedded calcilutites, some pinch and swell structures. Clays and marls with shell imprints. The dominant lithology is limestones with beds up to 1m in thickness, followed by common marls and a few shales.

Beds feather-out, calcilutites become more coarse with shelly fragments.

Red clays and thin red calcilutites.

Calcilutites appear uncoloured for 70 cm.

Bedding becomes planar and even at between 5 cm to 10cm.

12cm clay with yellow silty shale at base of fining-up sequence.

22 5-12cm calcilutites with a red veneer. Thick, blocky marls. Limestone beds often brecciated into large blocks.

23 Broken calcilutite beds with thick marls interbedded. Some shales present.

Textfig. 4.9.6 Lithological logs (5) of the River Meto sections (collected by Rose in 1990).

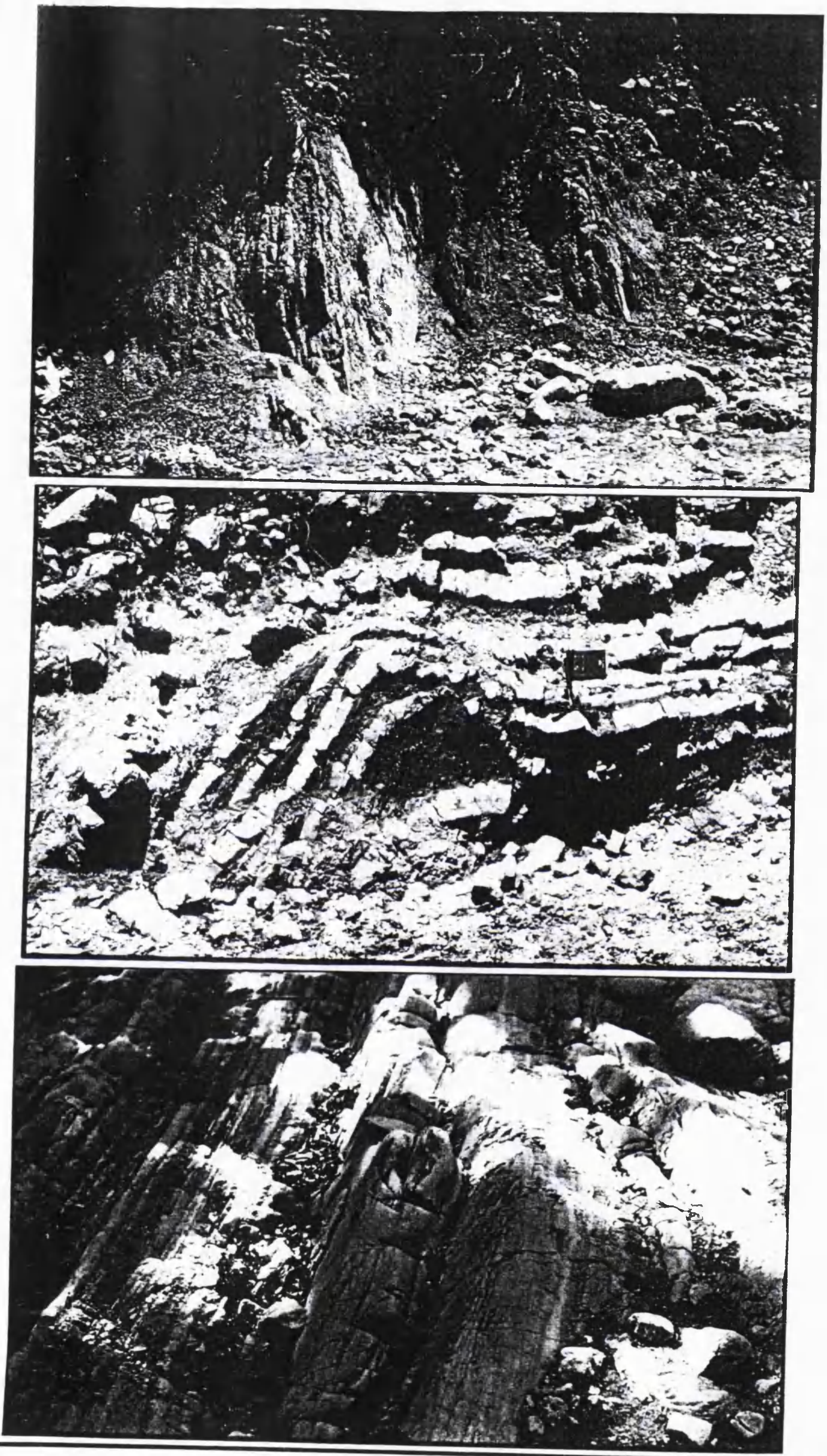


Plate A. Photographs of typical sample sections along the River Meto, Soe, West Timor
A =location 10, B =part of location 15, C=location 19

Chapter 5

Radiolarians in this study

5.1.0 Introduction

This chapter lists the families and genera recovered during the present study (Textfig. 5.1, 5.2, 5.3, 5.4). The position of each group (chapter and page number) within the text is also given in order to simplify access to the data and introduce radiolarian assemblage content before Chapter 6, which is concerned with biostratigraphy.

5.2.0 Late Triassic Radiolarians

Late Triassic age radiolarians studied herein are situated in Appendix 1 (pp. 191-361). An introduction to the problematic groups (pp. 175-189) explains the choices made with regard to the systematics used in this work. Triassic taxa are split into three types of systematic description

1) Significant or abundant taxa (pp. 191-357) are given a detailed systematic treatment i.e. contain an original description, synonymy, range, geographical occurrence, specimen measurements and are illustrated in the plates (1-26).

2) Taxa under the title of 'Lost' or 'Not illustrated' (pp. 358-361) contain an original description, synonymy, range, geographical occurrence, however, are not measured or illustrated in the plates.

3) Taxa listed under 'Rare' and 'Not Illustrated' (p. 361) are given no systematic treatment, however, these are still listed in the Range Charts situated in the sleeve.

Taxa are divided into three groups with varying degrees of systematic description to reinforce the significance of each species within this study. Those taxa without systematic description are rare and only occur in a limited number of samples. Those marked 'Lost' or 'Not illustrated' are believed to be biostratigraphically significant and were either lost before being photographed or were found after the plates were made and will be illustrated in future publications. Taxa given a full description with an illustration are believed to be vital within this study and generally occur frequently in a number of samples.

5.3.0 Early Jurassic Radiolarians

The Early Jurassic radiolarians (Textfig. 5.4) are far less abundant, diverse and are not as well-preserved as the Late Triassic taxa recovered during this study. All of the species of this age are listed in Appendix 2 (p. 362-384) and receive an abbreviated systematic coverage. Only data concerning the type species (where applicable), range, occurrence, and remarks are given for each species whether they are illustrated or not.

Family	Subfamily	Genus
	Spumellaria	
Pantanellidae	Capnodocinae	*Capnodoce* (p. 192-199) *Justium* (p. 199-200) *Loffa* (p. 200-203) *Renzium* (p. 203-205)
	Pantanellinae	*Betraccium* (p. 206-207) *Cantalum* (p. 207-210) *Gorgansium* (p. 210-213) *Pantanellium* (p. 213-215)
Capnucosphaeridae		*Capnuchosphaera* (p. 215-227) *Icrioma* (p. 227-228)
		Kahlerosphaera (p. 228-234)
		Sarla (p. 234-235)
		Vinassaspongus (p. 235-237)
		Spongostylus (p. 237-238)
Saturnalidae	Saturnalinae	*Kozurastrum* (p. 240-244)
	Palaeosaturnalinae	*Palaeosaturnalis* (p. 244-254) *Pseudoheliodiscus* (p. 254-256)
		Stauracanthocircus (p. 256-258)
		Orbiculiforma (p. 258-261)
	Triarcellinae	*Triarcella* (p. 261-263)
		Heliosoma (p. 263-265)
Hexaporobrachidae		*Pentaporobrachia* (p. 266-267) *Tetraporobrachia* (p. 267-270)
Paratriassoastridae		*Paratriasoastrum* (p. 271-272)
Patulibracchiidae	Patulibracchiinae	*Paronaella* (p. 273-278) *Crucella* (p. 278-278)
Hagiastridae	Hagiastrinae	*Homeoparonaella* (p. 280-281)

Textfig. 5.1 List of Late Triassic families, subfamilies and genera occurring in this study.

Family	Subfamily	Genus
	Spumellaria	
		Triassocrucella (p. 281-282)
Ferresidae		*Ferresium* (p. 283-285)
		Zhamojdasphaera (p. 285-286)
		Astrocentrus (p. 286-287)
		Spongoserrula (p. 287-288)
Xiphostylidae		*Archaeocenosphaera* (p. 289-290)
		Natraglia (p. 290-291)
		Pseudohagiastrum (p. 291-294)
	Nassellaria	
Bulbocyrtidae		*Bulbocyrtium* (p. 300-302)
Canoptidae		*Canoptum* (p. 303-305) *Pachus* (p. 306-307)
		Karnospongella (p. 307-308)
Palaeoscenidiidae	Pentactinocarpinae	*Pentactinocarpus* (p. 309-314)
	Syringocapsinae	*Dibolachras* (p. 314-316) *Syringocapsa* (p. 316-319)
		Tirodella (p. 319-320)
Xiphothecidae		*Xiphotheca* (p. 321-324)
Pseudosaturniformidae		*Pseudosaturniforma* (p. 324-326)
		Triassocampe (p. 326-327)
Neosciadiocapsidae		*Citriduma* (p. 327-329)
		Squinabolella (p. 330-334)
Deflandrecyrtiidae		*Deflandrecyrtium* (p. 334-338)
		Saitoum (p. 338-339)
Ruesticyrtiidae	Ruesticyrtinae	*Pararuesticyrtium* (p. 340-341)
		Wuranella (p. 341-342)
Entactiniidae		*Entactinosphaera* (p. 342-344)
		Veghia (p. 344-346)
Pseudodictyomitridae		*Corum* (p. 346-348)

Textfig. 5.2 List of Late Triassic families, subfamilies and genera occurring in this study.

Family	Subfamily	Genus
	Nassellaria	
		Bipedis (p. 349-350)
Livarellidae	←	*Livarella* (p. 350-353)
		Poulpus (p. 353-354)
		Pseudolivarella (p. 356-357)
		Globolaxtorum (p. 359-360)
		Parahsuum? (p. 360-361)
		Eucyrtidellium (p. 361)
		Yeharaia (p. 361)
		Tricolocapsa (p. 361)
		?Plafkerium (p. 361)

Textfig. 5.3 List of Late Triassic families, subfamilies and genera occurring in this study.

Spumellarian Genera

Archaeocenosphaera (p. 364)
Bistarkum (p. 365)
Crucella (p. 366)
Orbiculiforma (p. 367)
Paronaella (p. 368-370)
Praeconocaryomma (p. 370-372)
Rseudoaulophacus (p. 372)
Spongostaurus (p. 372-373)
Tetratrabs (p. 373-374)

Nassellarian Genera

Canoptum (p. 374-375)
Canutus (p. 375-376)
Hsuum (p. 376)
Katroma (p. 376-377)
Maudia (p. 377-378)
Perispheridium (p. 378-379)
Pseudoristola (p. 379-381)
Parahsuum (p. 381-382)
Rolumbus (p. 383)
Tricolocapsa (p. 383-384)
Archaeodictyomitra (p. 382-383)

Textfig. 5.4 List of Early Jurassic genera occurring in this study.

Chapter 6

Biostratigraphy

6.1.0 Introduction

The essential requirements for a reliable zonal indicator species are short range, abundance, ease of recognition and worldwide distribution (Carter, 1993). Only in recent years has the potential of radiolarians as biostratigraphic tools been recognised and the group is increasingly used in the study of Mesozoic rocks. It was originally believed that radiolarians were too small, too difficult to extract and use, and that the forms were too long-ranging for stratigraphic use. Over the last twenty years workers such as Riedel, Pessagno and Blome in North America, Baumgartner, De Wever, Kozur and Mostler in Europe, and Yao, Yoshida, and Nishimura in Japan and Yeh in Taiwan have undertaken detailed taxonomic and biostratigraphical analyses of Mesozoic radiolarians. The development of new techniques for extraction (with Hydrofluoric acid) and microscopy (scanning electron microscopy) have allowed rapid advances to be made in the study of radiolarians, as with other microfossil groups. At present a number of zonations have been proposed and are being refined with coverage through the Mesozoic and Cenozoic. This study focuses on the sediments of Late Triassic and Early Jurassic age of Timor which have yielded abundant, well-preserved and diverse assemblages of radiolarians, which occur in association with other groups such as conodonts, foraminifera, calcareous nannofossils and ostracods (NB. the Jurassic radiolarians in this study are dealt with more briefly than the Triassic).

6.1.1 Zonation types

Biostratigraphic schemes employ a number of different types of biozones: 1) Assemblage-zones (e.g. Textfig. 6.5) which are assemblages of fossils with one or more characteristic taxa and in the case of radiolarians are, where possible, cross-correlated on the co-occurrence of other index fossils (usually conodonts in this study). 2) Range zones (e.g. Textfig. 6.6) are based on and correlated with each other by the range of a taxa (e.g. the Late Triassic radiolarian *Betraccium deweveri* zone). 3) Interval zones (Textfig. 6.6) are defined by biohorizons which represent the first or last appearance level/datum planes (First Appearance Datum (FAD) and Last Appearance Datum (LAD)) of characteristic radiolarian species. Carter (1988) used two types of interval zones, these being: 1) Oppel zones, defined by International Subcommission on Stratigraphic Classification (ISSC) (Hedberg, 1976, p. 55, 57) as "Characterised by having more than two taxa, and having boundaries based on two or more documented first and/or last occurrences of the included characterising taxa", and 2) Interval zones, as defined by the North American Commission on Stratigraphic Nomenclature (1983, p. 863), are "The body of strata between two specified, documented lowest and/or highest occurrences of single taxa". Several correlatable international biozonations based on radiolaria have been published (Textfig. 6.7) and are discussed below. Other zones such as acme zones are not used in this study.

6.1.2 Methods used

Weathering and exposure are difficulties inherent in using biostratigraphic techniques in modern tropical and other areas in addition to the original production and preservational problems (i.e. winnowing and solution loss during sedimentation and diagenesis). The most significant is rapid weathering and erosion of outcrops which results in small sections with large gaps between. This incomplete mosaic can produce a great deal of useful data, however, gaps may create more problems than the useful data from outcrops may solve. During the course of this study small outcrops were the norm and gaps within the accessible stratigraphy were noted, although these were as much a result of folding and faulting as of weathering and erosion. Assemblage zones were used, as the ability to pinpoint first and last occurrences at specific horizons was generally not possible given the incomplete nature of the sampling. Precise counts were not used during this study as true variations may not be reflected in the assemblages for the following reasons:

a) Post-mortem dissolution of biogenic silica within the water column and after burial is likely to remove delicate forms leaving only the more robust radiolarians and so distort the original assemblage composition nature of an assemblage.

b) Preservation may be differential, with replacement by other minerals affecting the quality of the fossil test, which can affect ease and reliability of identification. This was not a problem encountered with the Upper Triassic studied here, however, many of the Lower Jurassic samples contained forms which had been replaced by calcite and so were difficult (in some cases impossible) to identify.

c) Loss (or replacement) to pore fluid solution during and after diagenesis.

d) Sedimentary compaction during diagenesis may destroy and/or distort delicate specimens, and in sediments collected for this study variation has been observed with lower assemblage diversity occurring in some lithologies (although this may reflect an original environmental feature).

e) Higher sedimentation rates may also apparently reduce the overall abundance of radiolarians in one sample in comparison with another i.e. sedimentary dilution.

f) Different lithologies often require different extraction techniques which may destroy some specimens during processing and, therefore, distort the assemblage composition. The sediments recovered in this work were mainly limestones, marls and shales. The marls were processed using warm water only, whereas limestones needed treatment with acids, possibly resulting in slightly different assemblages Differences were observed in this study with a general increase in species numbers occurring in softer lithologies (marls), however, this may be a result of original preservation.

g) Human factors such as sieving, analysing different size fractions, counting methods and consistant identification etc. may influence statistical results.

Whenever possible in this study (especially when good sections were encountered) ranges of genera and species were recorded and the particular section was placed within the overall range of the time interval studied. When a series of small faulted, repeated or folded sequences occur, which therefore may overlap in time, gaps were left on the charts between the sections.

6.1.3 Comparison with established stratigraphic zonations

The ranges of radiolarian taxa are, wherever possible, correlated with other fossil groups which are abundant in many of the samples from West Timor. Bown (1987a, 1992) and Bralower *et al.* (1991) have worked extensively on calcareous nannofossils of Late Triassic and Early Jurassic age from Europe, Southeast Asia and North America. Samples from this study containing nannofossils were recorded and identifications were made by Dr. P. R. Bown. Conodonts were also utilised, however, they were much more rare than other microfossil groups. Identifications of conodonts were made by Dr. L. Krystyn for Barkham (1993). Other fossil groups present include foraminifera, ostracods, bivalves (chiefly *Halobia*) and holothurians. These may form part of a future integrated micropalaeontological study.

In order to test the radiolarian biostratigraphy a comparison is made with results, primarily, from southeast Asia (Philippines) and other areas in east Asia such as Japan and China. Biostratigraphic data from further afield are also used, i.e. from other Tethyan areas such as Greece, Turkey, Sicily, Austria and Romania, and finally from western North America (Queen Charlotte Islands, Alaska, British Columbia, Oregon and California). Several zonation schemes (Textfig. 6.5, 6.6, 6.7) have been correlated by Yao (1991) on the basis of the similarity of radiolarian species composition (e.g. Yao *et al.* , 1982; Matsuoka and Yao 1986; Blome 1984; Murchey 1984; Baumgartner 1984, 1987, etc).

The upper part of the *Triassocampe nova* Assemblage-zone (Carnian to middle Norian) and the lower part of the *Canoptum triassicum* Assemblage-zone (middle to late Norian/Rhaetian in age) (Yao, 1982 in Textfig. 6.5, this study) are partly correlatable with the *Capnodoce* and *Betraccium* Zones of Blome (1984) in western North America. To-date, no Triassic zones have been recognised or defined in Europe, however, it is still possible to make approximate correlations based on the species composition found there. For the Lower Jurassic of western North America, several radiolarian biohorizons have been defined by Pessagno *et al.* (1987). Carter (1988, 1990, 1991, 1993) has carried out a study of the Late Triassic to Mid Jurassic aged radiolarians of the Queen Charlotte Islands, British Columbia. Her work is part of an integrated palaeontological investigation into Mesozoic strata of the islands of western Canada carried out by the Geological Survey of Canada. Excellently preserved radiolarian assemblages have been documented in great detail using, among other biostratigraphic techniques, Unitary Associations (Geux, 1991). This statistical method has allowed the recognition of more than 20 radiolarian associations. As part of this study the assemblages reported by Carter (1993) were observed under the microscope and directly compared with the assemblages recovered from Timor and both show a moderate degree of similarity at generic level. A full discussion of the correlation of the assemblages is undertaken at the end of this chapter.

6.1.4 Palaeobiogeography of Triassic and Jurassic Radiolarians

Baumgartner (1984), Pessagno (1986), and Blome (1987) recognised the potential of radiolarians in palaeobiogeographic studies of the Triassic and Jurassic. Blome (1987) was able to separate Upper Triassic and Lower Jurassic radiolaria into low, middle and high palaeolatitude assemblages. Using palaeolatitudinal parameters both Baumgartner (1984) and Pessagno (1986) believed that the Triassic and Jurassic radiolarian faunas of Japan were low-latitude, Tethyan assemblages. The Upper Triassic of the North Palawan Block in the Philippines appears to contain a different radiolarian assemblage from Japan and West Timor, indicating original geographical separation from the latter areas. Species composition of several other areas will be discussed below in comparison with the assemblages found during this study.

The following sections contain data from studies documenting the distribution of Triassic and Jurassic radiolaria from geographically widespread regions. Many taxa are common in the sediments from these areas, however, in some cases the absence of certain taxa is as important as the presence of others. Some assemblages may contain markedly different components and so it is important to determine why these variations occur (i.e. palaeoenvironmental variation, restriction of basins, preservation differences).

6.1.5 Stratigraphic problems

6.1.6 Introduction

This section deals with stratigraphic problems brought about by the variety of schemes used by different authors. The status of the upper stages of the Triassic has been debated for some time. The Rhaetian *sensu* Dagys (1988) has been adopted in this study. Modifications for radiolarian faunas by Carter (1993); Blome (1984) and others are added to the stage definition of the Rhaetian by Dagys (1988). The question of correct terminology when dealing with time-rock units and time units is also addressed below.

6.1.7 Late Triassic Stratigraphy

6.1.8 Introduction

The definition of the Upper Triassic and in particular the Rhaetian has been a major problem in stratigraphy for a number of years. Several regional definitions, overlapping of the Norian and Rhaetian and the general lack of worldwide distribution of the end Triassic stage have resulted in confusion. The status of the Rhaetian is still the subject of vigorous debate by The Subcommission on Triassic Stratigraphy. A spectrum of opinion exists concerning the status of the Rhaetian; whether it should be used at all, or as a stage or substage in the uppermost Triassic (see discussions in *Albertiana* 10, e.g. Tozer)

6.1.9 Early research

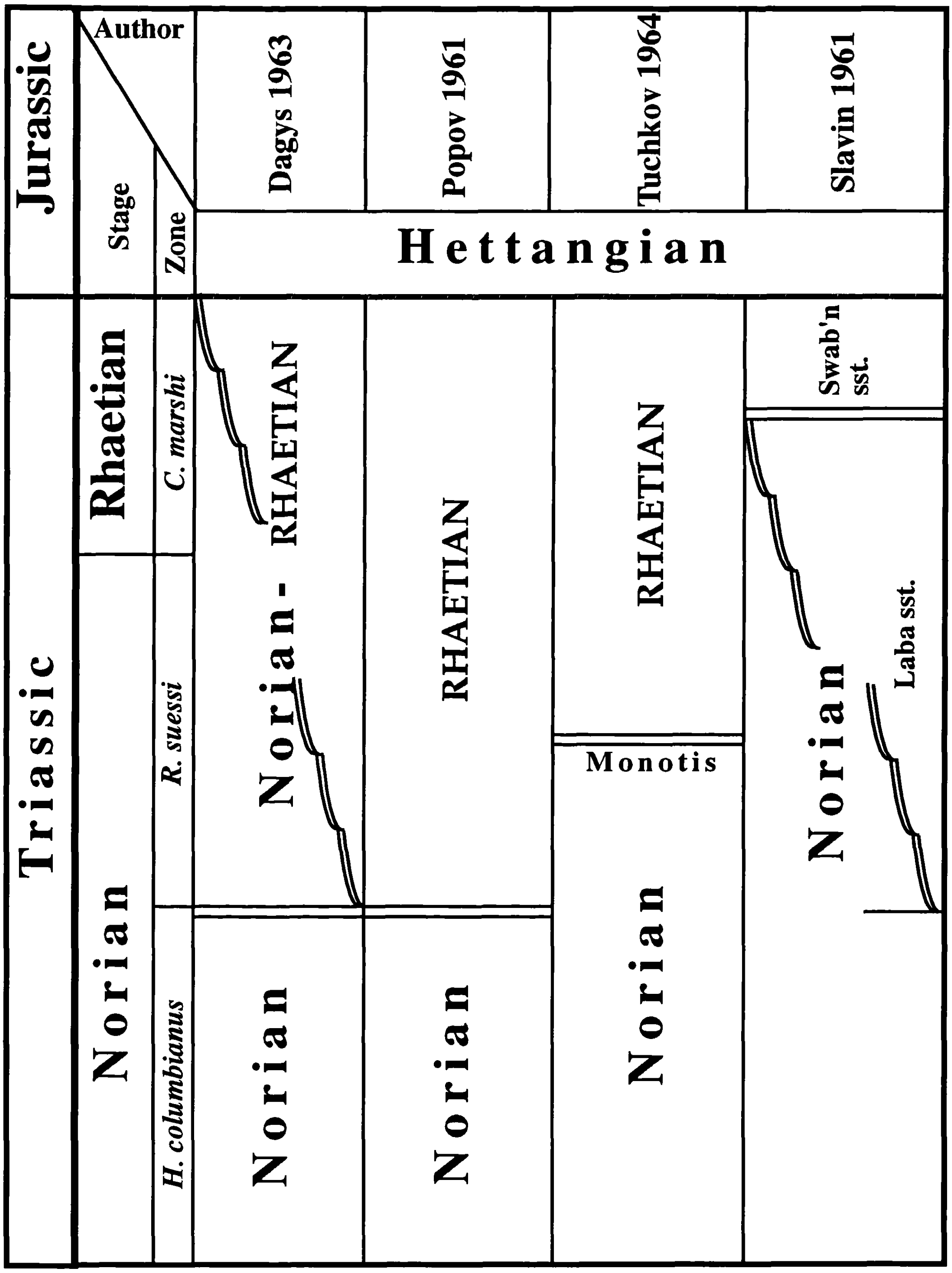
The early research into the stratigraphy of the Upper Triassic was carried out in Europe. Gümbel (1861) following the work of Buch (1831) and Oppel (1856) published a study of the geology of Bavaria and introduced new nomenclature for the alpine Triassic (Bunter, Muschelkalk and Keuper). It was in this work (Gümbel, 1861) that the Rhaetian was named from the Rhaetian Alps. Later, Mojsisovics (1869) recognised three stratigraphically separated ammonoid faunas in the Hallstatt area of the Austrian Alps and so divided the Late Triassic below the previously named 'rhaetische Gruppe' into a lower 'Noric' and upper 'Carnic'. This was later recognised as being the wrong way around and so the placement of 'Carnic' above 'Noric' was reversed. The Triassic was the subject of a great deal more research and controversy in the intervening years. Zapfe (1967) considered that the Norian near Gosau, Austria reached too high into the profile and therefore proposed that part of the Rhaetian may be represented by beds which yielded Norian ammonoids. Since the early 1960's research in Europe has thrown-up a number of stratigraphic problems mainly as a result of incomplete sections, geographically restricted faunal assemblages and the adoption of different schemes by different authors (Textfig 6.1).

In the course of the controversy over the status of the Rhaetian several suggestions have been made with the intention of improving the precision of the final stage of the Triassic ((Pearson, 1970) see Popov, 1961, Tuchkov, 1964, Slavin 1961, 1963). Popov (1961) suggested lowering the lower boundary of the Rhaetian to the base of the Sevatian Substage (see Textfig. 6.2), Tuchkov (1964) proposed the use of *Monotis salinaria* and its close relations to define this boundary, whereas Slavin (1961, 1963) put forward the notion that the alpine Rhaetian is merely a facies of the Norian and conceded that the French idea of the Rhaetian forming the initial stage of the Jurassic may be relevant. Pearson (1970) argued that although a little imprecise in Europe the Rhaetian should be retained as the youngest stage of the Triassic.

6.1.9.1 Recent changes in the status of the Rhaetian

More recently a number of schemes defining the status of the Rhaetian have been proposed (Tozer, 1979, 1980, 1984; Wiedmann *et al.,* 1979; Krystyn, 1980, 1988; and Dagys, 1988). Tozer (1979, etc.) has strongly argued that the Rhaetian is imprecise and is only useful for correlation in western Europe and does not belong as a stage in an international Triassic zonal hierarchy. In North America Tozer (1979, 1980, 1984, etc.) split the Norian into lower, middle and upper based on the occurrence of ammonoids from the region. The upper Norian consists of the Cordilleranus, Amoenum and Crickmayi ammonoid zones (equivalent to the Suessi and Marshi ammonoid zones of Europe (Tethys) and replaces the Rhaetian of some schemes (such as Wiedmann *et al.*, 1979 and Tollmann, 1985) (Textfig. 6.2).

The Subcommission on Triassic Stratigraphy in 1992, discussed the status of the Rhaetian and published the results of the discussion in *Albertiana* 10, November



Textfig. 6.1. Proposed Norian-Rhaetian, and Rhaetian-Hettangian boundaries (after Pearson 1970).

Stage	**Norian**								Tozer, 1979, 1980, 1984
Substage	Lower Norian			Middle Norian		Upper Norian			
Zone	*Kerri*	*Dawsoni*	*Magnus*	*Rutherfordi*	*Columbianus*	*Cordilleranus*	*Amoenum*	*Crickmayi*	

Stage	**Norian**				Wiedmann *et al.*, 1979 compromise
Substage	Lac	Alaun	**Rhaet**		
Zone			Suessi	Marshi	

Stage	**Norian**								**Rhat**		Krystyn, 1980, 1988
Substage	Lac			Alaun			Sevatian				
Zone	Jandianus	Paulckei	Magnus	Bicrenatus	Hogarti	Macer	Quinque-punctatus Subzone	Reticulatus Subzone	Stuerzenbaumi	Marshi	

Stage	**Norian**						**Rhat**		Tollmann, 1985
Substage	Lac			Alaun			Sevatian		
Zone	Jandianus	Paulckei	Magnus	Bicrenatus	Hogarti	Macer	Suessi	Marshi	

Stage	**Norian**		**Rhaetian**	Dagys, 1988
Substage		Sevatian		
Zone		Ochotica	Efimovae	

Textfig. 6.2 Various definitions of the Late Triassic and the status of the Rhaetian

1992. Until that time the Rhaetian was retained, but its status (stage or substage) was left open. A large majority of the subcommision voted for the Rhaetian to represent the ultimate stage of the Triassic. The voting favoured the Rhaetian *sensu* Dagys (1988), i.e. the that the base of the Rhaetian should be at the base of the Reticulatus Subzone (equivalent to the base of the Amoenum ammonoid Zone in North America).

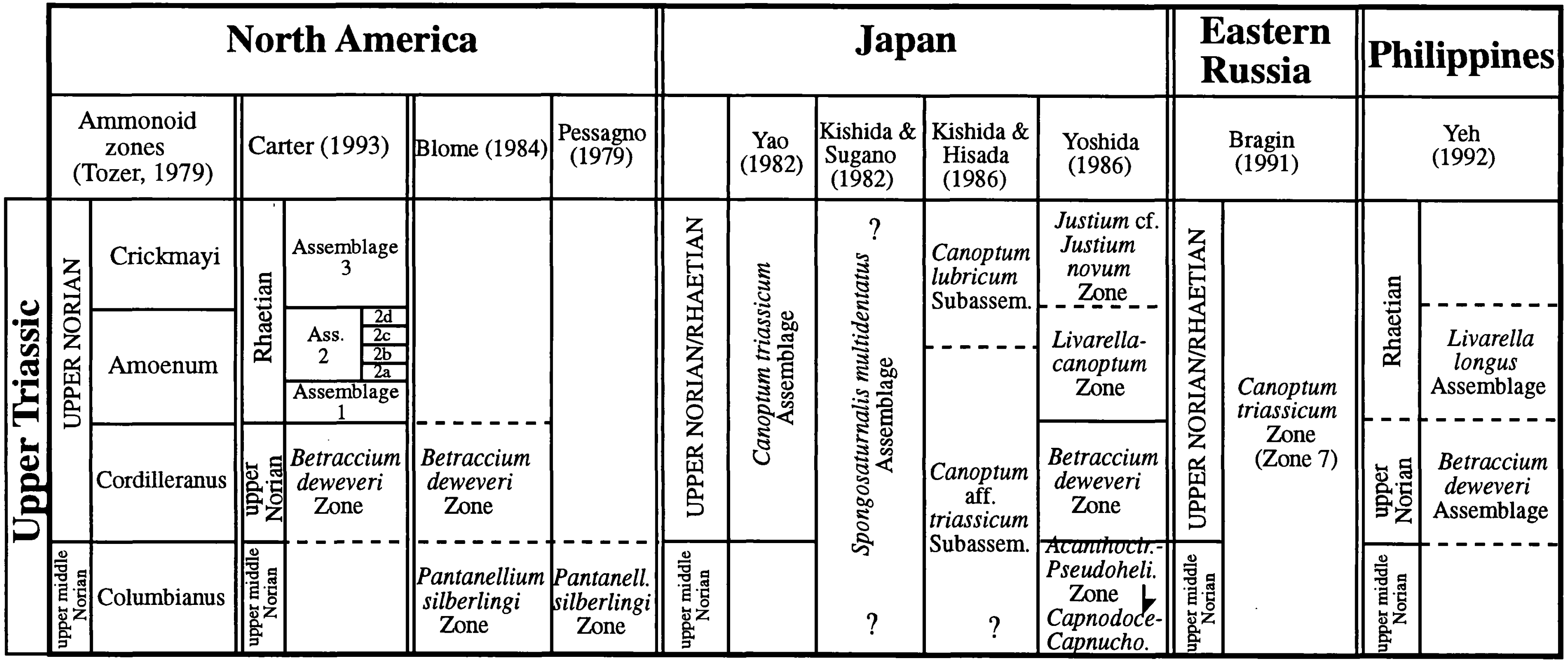
6.1.9.2 Discussion

Carter (1993) studied the radiolarians of the latest Triassic of the Queen Charlotte Islands. In her study she used the Rhaetian to cover the last two ammonoid zones of the Triassic (Amoenum and Crickmayi) and replaced the upper Norian (Cordilleranus, Amoenum, Crickmayi ammonoid zones) of Tozer (1979) with the Rhaetian and upper Norian below (with the upper Norian corresponding to the Cordilleranus zone only, see Textfig. 6.3). Other radiolarian specialists have used, upper Norian only (Blome, 1984), upper Norian and Rhaetian (Yao, Matsuda and Isozaki, 1980), as well as Rhaetian in the same sense as Carter (1993) (e.g.Yeh, 1992, although without supporting data from other fossil groups). For the purpose of this study the scheme adopted by Carter (1993) for radiolarians, is used for the Rhaetian; the *Betraccium deweveri* Zone of Blome (1984) is correlated the upper Norian.

6.1.9.3 Stratigraphic nomenclature

6.1.9.4 Introduction

The dual system of nomenclature in expressing the relative position in time of rocks and events has evolved over the last century or so (Haile, 1987). The international Stratigraphic Guide of the International Subcommission on Stratigraphic Classification (ISSC) Hedberg (1976) defines and explains the use of terminology. This guide makes clear the correct terminology and thus enables the user to clearly express complicated ideas concerning time rock units and events.



Textfig. 6.3 Upper Triassic Radiolarian Biostratigraphic schemes for North America, Russia and the Philippines

6.1.9.5 Definition of Chronostratigraphic and Geochronological units

The international consensus is as follows: Chronostratigraphic units (e.g. Cretaceous System, Eocene Series, Aptian Stage) are divided into lower, (middle) and upper parts are appropriate for use in describing the age of rocks, Geochronological units (e.g. Cretaceous Period, Eocene Epoch, Aptian Age) are divided into early (mid), and late and are appropriate for designating the time of occurrence of historical events, such as transgressions, periods of erosion, sedimentation etc. (Haile, 1987). A distinction between the various chronostratigrahpic and geochronological units is given below (Textfig. 6.4).

Time-rock units are, in principle, defined by reference to an internationally agreed type section and so the postion of rocks within these units is determined by correlation to the type sections by using fossils, palaeomagnetics, lithology etc. This being the primary observable unit therefore the time unit is secondary and is derived from this (Haile, 1987). For the purposes of this study the ICCS guide (Hedberg, 1976) is used.

6.2.0 Biostratigraphy of the Philippines

6.2.1 Introduction

The Philippines are geographically proximal to the present day location of eastern Indonesia. The islands of the Philippines are the result of late Mesozoic and Cenozoic polyphase evolution and consist of accreted volcanic arcs, marginal basins, ophiolites and continental fragments (Barrier *et al.* 1991). Hamilton (1979) and Isozaki and Nishimura (1987) postulated that the North Palawan Block (sampled as part of a radiolarian study by Yeh (1990)) was, at one time, situated at a Late Mesozoic convergent margin of Southeast Asia. This 'displaced microplate' was detached from mainland China during the mid Oligocene and early Miocene (Hamilton, 1979). Similar units are found in southwestern Japan, Ryukyu and therefore are of interest in correlating the geological history of these terranes with other parts of Southeast and East Asia.

Chronostratigraphic (time-rock) units	**Geochronological (time) units**
1) A primary unit of **age**, defined by a section (from base of the unit 'golden spike' to the base of the overlying unit). This consists of all **rocks** of the same **age** as the type section.	1) A derived unit as the **time** represented by the equivalent chronostratigraphic unit. Applied to all **events** which occur within the defined **time span**.
2) Appropriate for designating the **age** of rocks and relationships observable at present such as strata, formations, biostratigraphic zones, unconformities. and faulting etc.	2) Appropriate for designating the **time of occurrence** of geological events such as: depositional and erosional episodes, folding, faulting. faunal extinctions, mineralisation, oil generation and migration.
3) Presence is recognised by correlation to local reference sections and ultimately to the type section, using all available evidence.	3) Timing of events is deduced from their effect preserved within or relative to dated rocks.
Divided into lower (middle), upper	Divided into early (mid), late
Unit has a base and a top	Unit has a beginning and an end
Unit has a **thickness** which varies from place to place	Unit has a **duration** which is fixed
Part or all of the unit may be absent in any specific area	Unit, being a defined periods of time, was ubiquitous and unvaried.

Textfig. 6.4 Distinction between chronostratigraphic and geochronologic units (after Haile, 1987).

6.2.2 Triassic biostratigraphy of the Philippines

Cheng (1989) reported several radiolarians (often the only fossils present) from islands in the North Palawan Block, including Middle Triassic assemblages. Cheng (1989) recovered Permian to Triassic radiolarians from a bedded chert sequence from the Calamian Islands group, North Palawan Block. Yeh (1990) continued research of Cheng (1989) into the Mesozoic radiolarians from these islands in the western Philippines. Three radiolarian assemblages were recognised by Yeh (1990) (Textfig. 6.3) and reported, all three from Busuanga Island. The oldest is the *Busuanga chengi* Assemblage which is Middle Triassic (Ladinian) in age and has *Archaeosemantis* sp. A, *Busuanga chengi, Eptingium manfredi, Parentactinia nakatugawaensis, Parentactinia* sp. B, *Pseudostylosphaera japonica, Pseudostylosphaera spinuosa, Pylostephanidium* sp. A, *Tiborella* sp. A, *Triassocampe annulata,* and *Triassocampe deweveri. Pseudostylosphaera* is also important in the younger (Late Triassic) assemblages of Yeh (1990). The *Trialatus megacornutus* Assemblage consists of: *Capnuchosphaera contracta, Capnuchosphaera crassa, Capnuchosphaera triassica, Cryptostephanidium japonica, Hozmadia reticulata, Kharlerosphaera philippinensis, Pseudostylosphaera japonica, Spongosilicarmiger italicus, Trialatus longicornutus, Trialatus megacornutus, Triassocampe deweveri* and *Yeharaia* sp. A. Yeh (1990) noted that the presence of *Capnuchosphaera* and *Pseudostylosphaera* indicated an early to late Carnian age and the first appearance of *Capnodoce* was later than that of *Capnuchosphaera.* The genus *Trialatus* is commonly found in samples from the Philippines, whereas it does not occur in West Timor. The youngest of the three units (including the *Betraccium deweveri* zone) proposed by Yeh is the *Livarella* sp. Assemblage consisting of *Betraccium macleani, Capnodoce* sp. cf. *C. malaca, Capnodoce primaria, Capnodoce venustus, Livarella* sp. A, *Pseudoheliodiscus gracilis, Pseudoheliodiscus palawanensis, Pseudoheliodiscus* sp. A Late Triassic (Norian) age is indicated for this assemblage by the presence of *Livarella, Capnodoce,* the absence of *Capnuchosphaera* and the diversification of *Pseudoheliodiscus.*

Yeh (1992) carried out a study of Upper Triassic cherts from Uson Island in the North Palawan Block close to Busuanga Island. The assemblage recovered from Uson Island differs in certain aspects from those of Busuanga Island. Two assemblages were recognised, the upper Norian *Betraccium deweveri* Assemblage and the lower Rhaetian *Livarella longus* assemblage.

Betraccium deweveri Assemblage

The characteristic taxa are: *B. deweveri, Betraccium chengi, Pantanellium inornatum, P. ultrasincerum* and *Canoptum laxum.* Most of the above taxa have not been recovered from Busuanga Island. The age is upper Norian from the presence of *Betraccium deweveri,* however, according to Blome (1984) the first occurrence of *B. deweveri* is lower upper Norian (North American scheme) whereas Yoshida (1986) and Yeh (1990) state that *Livarella* is only present in rocks younger than late Norian (absence of *Livarella* defines the age here).

Livarella longus Assemblage

This assemblage is defined by the presence of predominantly *Livarella* forms (*Livarella longus, L. densiporata, L. gifuense, L. inflata,* and *L. usonensis.* The age of this assemblage according to Yeh (1990) is early Rhaetian with a distinct and different *Livarella* assemblage from that of Busuanga Island discussed above.

There is a direct correlation between the distinctive *Livarella* assemblage found on Uson Island and samples recovered from West Timor. The six-rayed 'livarellids' (called *Citraduma* De Wever (1982) by Carter (1993) are described by Yeh (1990) and are taken from Oregon, and called *Citraduma* herein) are recovered in samples from this study along with nine-rayed forms. These have been reported from the upper Norian and Rhaetian of the Queen Charlotte Islands by Carter (1993), although other aspects of the assemblage are different from the present study in Indonesia. *Betraccium deweveri* has been recovered from the same assemblage as *Citraduma,* in this study

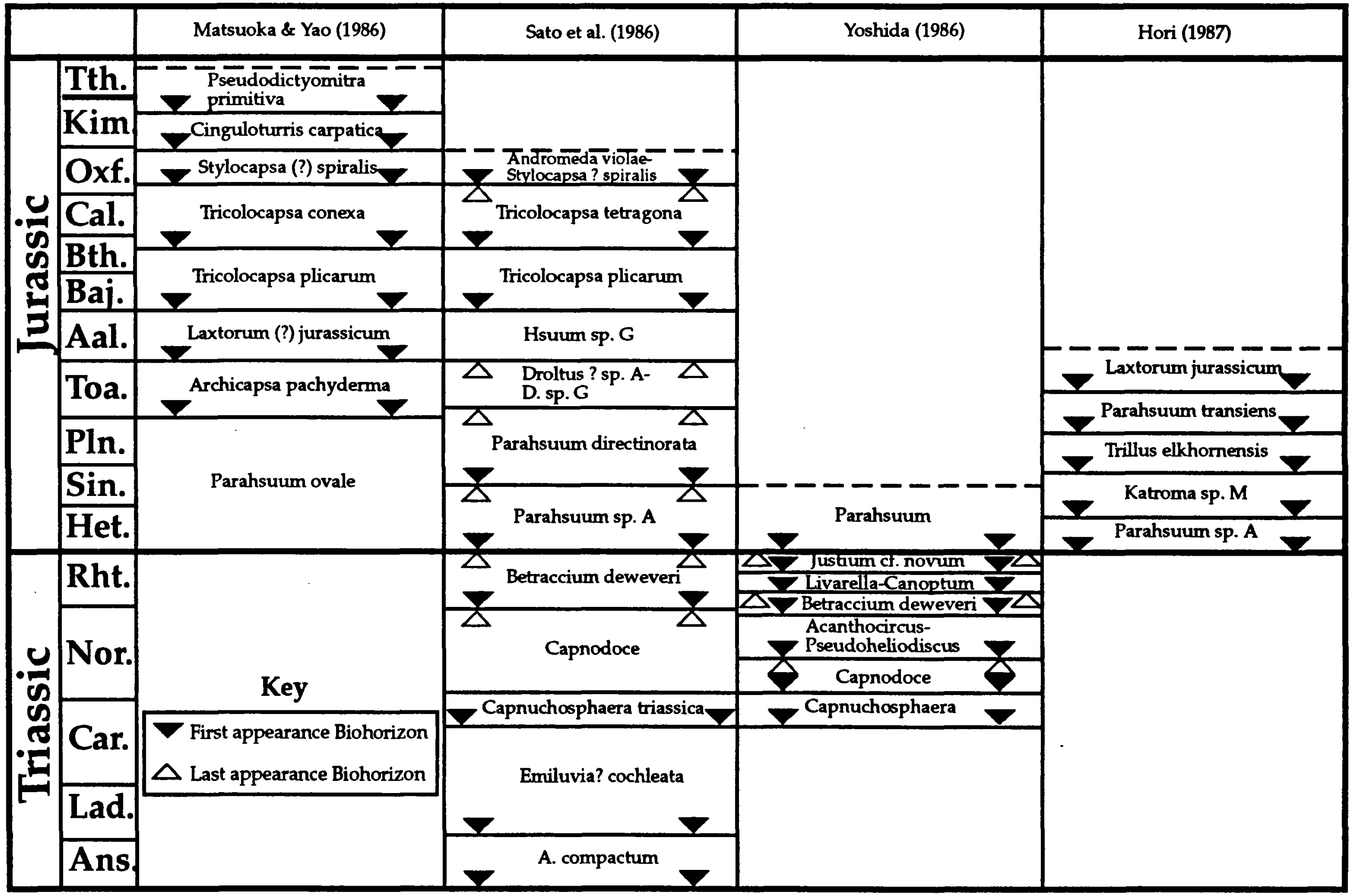
6.2.3 Biostratigraphy of Japan

6.2.4 Introduction

Yao (1991) reviewed the most significant publications from Japan and their biostratigraphic schemes (Textfig. 6.5, 6.6). The study of Mesozoic radiolarians in this area began with Yehara (1927), however, with the exception of Huzimoto (1938) little biostratigraphically significant work was carried out until the 1970's. Yao (1972) published a paper which illustrated Mesozoic saturnalid radiolarians in detail. These early studies and more recent work have used conodonts to tie in the radiolarian assemblages to the international stage stratigraphy. Most significantly, improved extraction techniques (using Hydrofluoric acid) allowed Japanese workers to observe specimens removed from chert, the most common radiolarian-bearing

Textfig. 6.5 Triassic and Jurassic assemblage zones for Japan (after Yao, 1991)

		Yao (1982) Yao et al. (1992)	Kishida & sugano (1982) Kishida & Hisada (1986)	Nishizono & Murata (1983)	Igo & Nishimura (1984)	Sashida & Igo (1985)	Hori (1987)
Jurassic	Tth.	Pseudodictyomitra primitiva- P. sp. A	Mirifusus mediodilatatus	M. mediodilatatus P. cf. carpatica			
	Kim.	Tricolocapsa yaoi				Mirifusus mediodilatatus	
	Oxf.	G. sakawaensis- S. naradaniensis	Mirifusus guadalupensis	Andromeda violae- M. mediodilatatus		Mirifusus guadalupensis	
	Cal.	Guexella nudata	Guexella nudata			Guexella nudata	
	Bth.	Unuma echinatus	Unuma echinatus	Zartus jurassicus		Unuma echinatus	
	Baj.						
	Aal.	Hsuum hisuikyoense	Spongocapsula? sp. A			Hsuum sp. A	Hsuum hisuikyoense
	Toa.	Parahsuum (?) grande	Parvicingula gigantocornis			Bagotum sp. A	Parahsuum (?) grande Acanthocircus hexagonus
	Pln.	Parahsuum simplum	Bagotum pseudoerraticum	Archaeodictyomitra directiporata- Eucyrtidium sp. A	Parahsuum simplum- Gigi sp.	Parahsuum simplum	Parahsuum simplum
	Sin.						
	Het.			A. sp. A- Triassocampe sp. A			
Triassic	Rht.	Canoptum triassicum	Palaesaturnalis multidentalis		Canoptum triassicum		
	Nor.	Triassocampe nova	Capnodoce anapetes	Capnodoce anapetes	Capnodoce anapetes- C. sarisa		
	Car.		Eptingium manfredi				
	Lad.	Triassocampe deweveri	Emiluvia? cochleata	Emiluvia? cochleata			
	Ans.						



Textfig. 6.6 Triassic and Jurassic radiolarian interval and range-zones for Japan (after Yao, 1991)

lithology in the islands of Japan.

Japan consists of a series of adjacent terranes which have affinities with the geology of northeast China. Isozaki and Nishimura (1988) demonstrated an extension of a geotectonic unit to Japan from the island of Ryukyus. Cheng (1989) reported a Palaeozoic to Mesozoic sedimentary complex in the Philippines which is similar to those of the Japanese terranes. The occurrence of Jurassic olistostromal mélange together with recent palaeontological descriptions and the development of new tectonic interpretations lead to speculation that most of the island-arcs in the western Pacific region are essentially of similar origin, having formed along a continental margin to which Upper Palaeozoic seamounts were accreted (Mizutani and Kojima, 1992). Japan therefore offers an insight into the palaeontological variations and/or affinities which may have occurred to the north, away from the continental margin of Australia.

6.2.5 Late Triassic Biostratigraphy of Japan

Two types of biostratigraphic schemes have been recognised by the Japanese palaeontologists. Firstly, assemblage-zones were established by (Yao, 1982; Yao *et al.*, 1982; Kishida and Sugano, 1982; Nishizono and Murata, 1983; Igo and Nishimura, 1984; Kishida 1986). These have been useful for general correlation and age assignment (Yao, 1991). More recently, increased precision has been possible with radiolarian zonations based on biohorizons (see Matsuoka and Yao, 1986, Yoshida, 1986) forming range and interval zones.

Nakaseko and Nishimura (1979) recognised three radiolarian assemblages from the Late Triassic of southwest Japan: the *Capnuchosphaera theloides*, *Tripocyclia* cf. *acythus* and *Emiluvia* (?) *cochleata* assemblages. The first contained species of *Capnuchosphaera, Capnodoce, Syringocapsa* and *Poulpous,* and is similar to assemblages recovered from Timor during this study. Yao (1982) distinguished four radiolarian assemblages from the Mino Terrane: *Triassocampe deweveri, Triassocampe nova, Canoptum triassicum,* and *Parahsuum simplum* covering the Middle and Upper Triassic and Lower Jurassic. These contain species which are routinely recovered from the sediments studied during this study.

Kishida and Sugano (1982) erected five assemblage zones for the Triassic of the

Chichibu Belt, Japan. The oldest was the *Emiluvia? cochleata* (Anisian-Ladinian boundary) followed by *Eptingium manfredi* (Ladinian-Carnian boundary), *Capnodoce anapetes* (Carnian-Norian boundary) *Spongosaturnalis multidentatus* (later changed to *Palaeosaturnalis multidentatus*) for the upper Norian and Rhaetian.

Kishida and Hisada (1985) carried out an extensive study of the Ueno-mura area in the Kanto Mountains of central Japan. Two subassemblages were recognised within the Norian-Rhaetian *Palaeosaturnalis multidentatus* Assemblage zone. These were the *Canoptum* aff. *triassicum* subassemblage consisting of *Palaeosaturnalis multidentatus, P.* cf. *triassicum* , *P.* cf. *quinquespinosa, Pseudoheliodiscus finchi,* and *Gorgansium gongyloideum.* The younger *Canoptum lubricum* subassemblage zone is characterised by *Canoptum lubricum, Palaeosaturnalis multidentatus, Pseudoheliodiscus finchi, Gorgansium gongyloideum, G. crassum,* and *Orbiculiforma multifora.*

Yoshida (1986) defined seven radiolarian zones (Textfigs. 6.3, 6.6, 6.9.4) covering the Upper Triassic to Lower Jurassic of Gifu Prefecture, Central Japan. The faunal assemblages of Yoshida (1986) are recovered from continuous sequences of chert which enables an apparently unbroken time interval to be studied. Only radiolarians were recovered from the samples and therefore age determination was based on a comparison with other, integrated, radiolarian faunal sequences in the nearby Inuyama area. This lack of index fossils from other groups for calibration is unsatisfactory, however, detailed relative abundance data proved to be a useful tool. Yoshida (1986) reported 43 genera and 150 species and used the first and last appearances of characteristic forms (genera and species) to construct the zones (*Capnuchosphaera, Capnodoce, Acanthocircus-Pseudoheliodiscus, Betraccium deweveri, Livarella-Canoptum, Justium* cf. *J. novum* and *Parshsuum* Zones).

1) *Capnuchosphaera* Zone

This is the oldest zone and appears to be Carnian to late Carnian in age. The zone is characterised by the occurrence of members of the genus *Capnuchosphaera,* in particular *C. sockensis, C. theloides, C. tricornis, C.* cf. *C. schenki, C.* sp. A and *C.* sp. B (of Yoshida, 1986) and *Kahlerosphaera* cf. *K. parvispinosa.* The base is defined by the first occurrence of *Capnuchosphaera* with *Kahlerosphaera.*

2) *Capnodoce* Zone

The first occurrences of *Capnodoce anapetes* and *C. antiqua,* with the *Canesium* species group first found just above the base of the zone is characteristic. The top of the zone is significant for the last occurrence of *Capnodoce* (in particular *C. traversi, C. miniscula, C.* cf. *C. malaca, C. antiqua, C. fragilis, C.* cf. *C. kochi, C. beaulieui* and *C. anapetes*) and *Triassocampe, Napora* and *Canesium.* Nakaseko and Nishimura (1979) reported that *Capnodoce anapetes* and *C. sarisa* occurred within the *Capnuchosphaera theloides* Zone (early Norian). Pessagno *et al.* (1979) indicated that the *Capnodoce* species group of the *Capnodoce* Zone was early Norian in age (based on ammonites and *Halobia* in N. America). Yoshida (1986) suggested that the correlations indicate that this zone may, in fact, be as old as late Carnian.

3) *Acanthocircus-Pseudoheliodiscus* Zone

The final occurrence of the *Capnodoce* species group defines the base of this zone. The characteristic species of this zone include: *Acanthocircus heisseli, A. convertus, A. zapfei, A.* cf. *A. elegans,* and *Pseudoheliodiscus quadriradiatus.* Yao (1982) reported that the *Acanthocircus* species group and *Pseudoheliodiscus* species group were included in the *Triassocampe nova* and *Canoptum triassicum* assemblages respectively (mid to late Norian). Yoshida (1986) commented that the saturnalid species of Kishida and Sugano (1982) were very similar to the species from Europe reported by Kozur and Mostler (1972) and are in turn similar to some forms recovered during this study. The *Acanthocircus* species group, as reported from North America by Blome (1984), is included in the *Capnodoce* Zone (late Carnian-mid Norian). Yoshida (1986) inferred that the *Acanthocicus-Pseudoheliodiscus* Zone in the Kagamigahara section (Japan) is as old as middle Norian. This zone is split into two subzones by Yoshida (1986) the *Acanthocircus* Subzone (oldest) and the *Pseudoheliodiscus* Subzone (youngest).

4) *Betraccium deweveri* Zone

The base is defined by the first occurrence of *Betraccium deweveri,* which also defines the top of the zone by its last occurrence, forming a total range zone. Another characteristic species is *Xenorum* cf. *X. largum.* Blome (1984) defined a subzone within the range zone of *Betraccium deweveri* by the co-occurrence of *B. deweveri, B. inornatum, B. maclearni* and *B. yakounense* from the late Norian of Northwest America and so is considered to be that age.

5) *Livarella-Canoptum* Zone,

The base of this zone is defined by the final occurrence of *Betraccium deweveri* and the first occurrence of the *Livarella* species group. Yoshida (1986) reported that several species of *Dreyericyrtium* (?) occur near the base of this zone.The section of Yoshida (1986) has its base defined by the first occurrence of *Livarella validus, L. longus, Dreyericyrtium* (?) sp. A and *D.* (?) sp. B. The top of this zone is is marked by the first occurrence of *Justium* cf. *J. novum* from the zone above. The age is ?early to mid Rhaetian. Characteristic species of this zone include: *Livarella densiporata, L. validus, L. longus, L. gifuensis, L.* sp. A, *Canoptum laxum, C. farawayanse, C. triassicum, Dreyericyrtium* (?) sp. A, *D.* (?) sp. B, and *Ferresium* sp. A. The species assemblage of the *Livarella-Canoptum* Zone is almost identical to that of Sample SB 220 (this study), however, *Betraccium deweveri* is present with forms of *Livarella, Canoptum* and the distinctive Nassellarian gen, and sp. indet C. The zone as defined by Yoshida (1986) is divided into two subzones, the older *Livarella* Subzone and th*Canoptum* Subzone.

6) *Justium* cf. *J. novum* Zone
The base of this zone (occurs in the ?late Norian to Rhaetian) is defined by the first occurrence of *Justium* cf. *J. novum* which is found throughout the zone, forming a range zone with the final occurrence of *Livarella densiporata* and the first appearance of *Parahsuum* group. Species characterising this zone include: *Justium* cf. *J. novum, Livarella densiporata, Canoptum triassicum, Tripocyclia* sp. A, *Dictyomitrella* sp. A. The *Justium novum* Subzone, according to Blome (1984) from western North America, is within the *Capnodoce* Zone making *Justium* cf. *J. novum* Zone of Yoshida (1986) biostratigraphically different from the *Justium novum* Subzone of Blome (1984).

7) *Parahsuum* Zone
This is the youngest zone defined from the Kagamigahara section, Central Japan. The base of the zone is defined by the first occurrence of the *Parahsuum* group and final occurrence of *Justium* cf. *J. novum.* The top of this zone is not defined.

The work of Yoshida (1986) is one of the more significant studies of the Upper Triassic of Japan and exhibits clear similarities with other areas around the world (see Textfig. 5.7) and with the samples recovered during this study.

6.2.6 Biostratigraphy of China

6.2.7 Introduction

Kojima and Mizutani (1987) carried out a taxonomic study of radiolaria from the Triassic and Jurassic of the Nadanhada Range in northeast China. Although their study was mainly taxonomic several important conclusions may be made based on the assemblages of species described.

6.2.8 Triassic Biostratigraphy of China

Kojima and Mizutani (1987) described an assemblage which contained the following species: *Pseudostylosphaera japonica, Triassocampe deweveri, Yeharai annulata, Y. elegans, P. japonica* and *Poulpus curvispinus.* The species found are characteristic

Textfig. 6.7 Triassic and Jurassic international radiolarian correlation zones (modified after Yao, 1991)

		Yao (1982) Yao et al. (1982) -Japan	Matsuoka & Yao (1986)- Japan	Blome (1984)- N. America	Carter (1993) Queen Charlotte Is.	Pessagno et al. (1987) N. America
Jurassic	**Tth.**	Pseudodictyomitra-primitiva- P. sp. A	Pseudoctyomitra primitiva			Zone 4 Zone 3 Zone 2
	Kim.	Tricolocapsa yaoi	Cinguloturris carpatica			
	Oxf.	G. sakawaensis S. naradaniensis	Stylocapsa ? spiralis			Superzone 1: (Not subdivided)
	Cal.	Guexella nudata	Tricolocapsa conexa			Zone 1G
	Bth.	Unuma echinatus	Tricolocapsa plicarum			Zone 1F
	Baj.					Zone 1B -Zone 1E
	Aal.	Hsuum hisuikyoense	Laxtorum? jurassicum			Zone 1A
	Toa.	Parahsuum (?) grande	Archicapsa pachyderma			Zone 01 Zone 02
	Pln.	Parahsuum simplum	Parahsuum ovale			Zone 03
	Sin.					Zone 04
	Het.					Zone 05
Triassic	**Rht.**	Canoptum triassicum		Betraccium	Assemblage 1 Assemblage 2 Assemblage 3 Betraccium deweveri	Zone 06
	Nor.	Triassocampe nova		Capnodoce	Assemblage 2: 2d 2c 2b 2a	
	Car.					
	Lad.	Triassocampe deweveri				
	Ans.					

of the *Triassocampe deweveri* Assemblage of Yao (1982) which is Ladinian in age. Other samples yield the distinctive *Capnodoce, Capnuchosphaera* and *Livarella* genera, therefore an age range of Carnian to Rhaetian may be assigned to these samples. Kojima (1989) illustrated examples of radiolarians from the Mino area, southwest Japan and the Nadanhada area, northeast China in order to show the similarity of forms. The following species were compared with examples from China and Japan (Kojima, 1989 plate 1): *Pseudostylosphaera japonica, Yeharaia annulata, Triassocampe deweveri, Eucyrtis* (?) sp. 4a, *Eptingium* sp. 5a, *Livarella validus, Parahsuum* (?) sp. A, *Acanthocirucus* sp. 8a.

6.3.0 Biostratigraphy of North America

6.3.1 Introduction

Studies of the Triassic and Jurassic radiolaria of North America are concentrated along the western continental margin from Baja California, California, Oregon, British Columbia and Alaska. All of these areas belong to the Cordillera, which is a series of terranes emplaced against the North American craton. The Wrangellia Terrane is the region that has been most often studied by radiolarian workers.

6.3.2 Late Triassic Biostratigraphy of North America

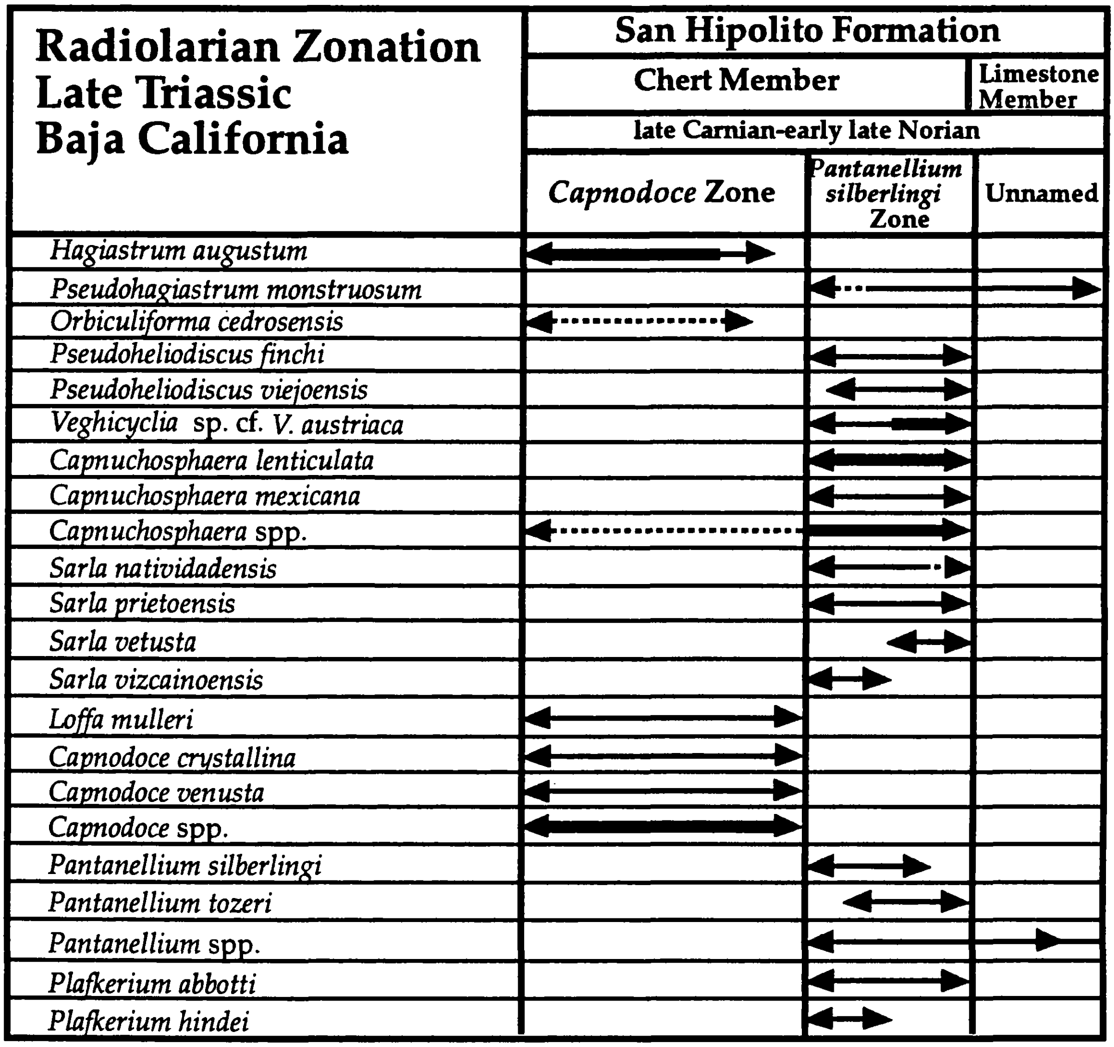
Pessagno *et al.* (1979) conducted a study of Upper Triassic radiolaria from San Hipolito, Baja California. An assemblage of diverse and fairly well-preserved radiolarians containing 25 new species and eight new genera was described. Two Oppel Zones (Textfig. 6.8) were defined from this area, and these are as follows:

1) *Capnodoce* Zone

The total range of the *Capnodoce* species group defines the zone with the base and top being pinpointed by the first and last occurrences of the genus *Capnodoce.* Characteristic species are *Hagiastrum augustum, Orbiculaforma cedrosensis, Loffa mulleri, Capnodoce crystallina, C. primaria,* and *C. tenusta.* The age of this zone in North America is late Carnian (?), early Norian to late middle Norian.

2) *Pantanellium silberlingi* Zone

The base of this zone is defined by the first occurrences of the following species: *Pseudohagiastrum monstruosum, Pseudoheliodiscus finchi, Veghicyclia* sp. cf. *V.*



Textfig. 6.8 Species ranges for some Upper Triassic radiolarians from Baja California (after Pessagno *et al.*, 1979)

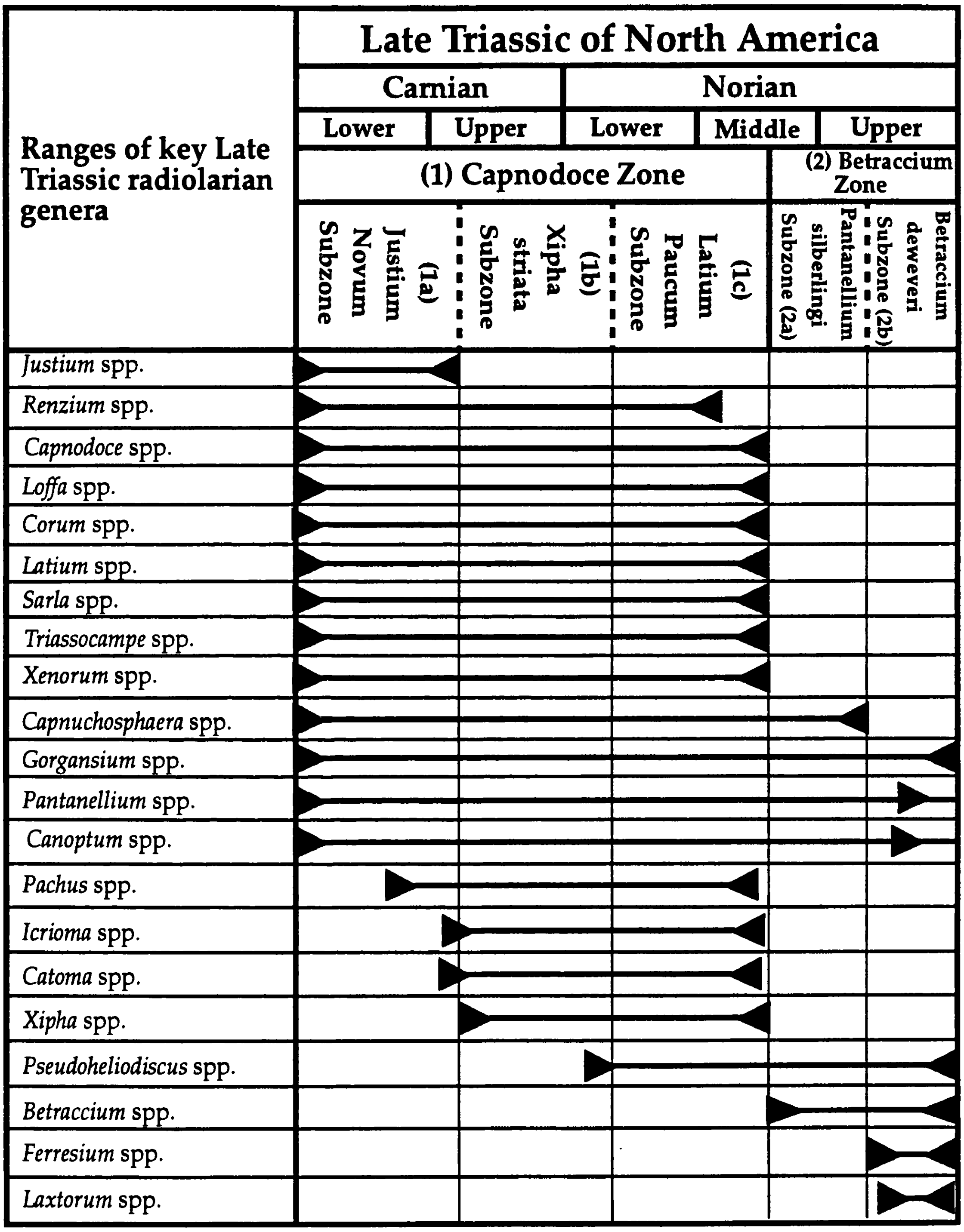
austriaca, Capnuchosphaera lenticulata, C. mexicana, Sarla natividadensis, S. prietoensis, S. vizcainoensis, Pantanellium silberling, Pflakerium abbotti, and *P. hindei.* The first occurrence of *Pantanellium* was regarded by Pessagno *et al.* (1979) as the most significant event in terms of biostratigraphy. The top of this zone is defined by final appearances of *Pseudoheliodiscus finchi, Pseudoheliodiscus viejoensis, Veghicyclia* sp. cf. *V. austriaca, Capnuchosphaera lenticulata, C. mexicana, Sarla natividadensis, S. prietoensis, S vetusta, Pantanellium tozeri,* and *Pflakerium abbotti* below an unnamed zone *Capnuchosphaera* is more abundant than in the *Capnodoce* Zone.

Blome (1984) produced a zonation for the Upper Triassic of North America with two zones and five subzones and produced a range chart for the genera found (Textfig. 6.9). Pessagno and Blome (1980) completed a detailed taxonomic study of the Pantanellidae and Blome (1983) described two biostratigraphically significant groups (the Capnuchosphaeridae and Capnodocinae) from Oregon. Samples for his study in North America were taken from eastern Oregon, Baja California and the Queen Charlotte Islands and correlated with those containing ammonites and pelycypod bivalves (*Halobia*). Blome (1984), concentrated on the Vester, Rail Cabin Mudstone and the Fields Creek Formation in eastern Oregon consisting of chert-grain sandstones, volcaniclastics, silt and mudstones. Limestone turbidites found in Oregon are similar to those found in the Soe sections as they were fed from local carbonate platforms. In the Queen Charlotte Islands samples were taken from the Karmutsen and Kunga Formations; the former consists of some lavas, later intrusive dykes and minor limestones, the latter limestone and siliceous mudstones with limestone nodules containing well-preserved radiolarians. The Upper Triassic of the Queen Charlotte Islands may represent a portion of a large allochthonous terrane that extends along the Pacific margin of North America from Vancouver Island to southern Alaska (Blome, 1984). This terrane was named as Wrangellia (Jones, Silberling and Hillhouse, 1977) and is believed to have originated in a position far to the south of its present day location as part of a volcanic sequence overlain by inner platform carbonate sediments and then finer grained basinal deposits. The sequences found in eastern Oregon are similar and are thought to be a detached part of Wrangellia.

The radiolarian zonation scheme of Blome (1984) utilised either interval or Oppel zones as follows:

1) *Capnodoce* Zone

As discussed above this has its base defined by the first occurrence of *Capnodoce* with



Textfig. 6.9 Ranges of Upper Triassic radiolarian genera from North America (after Blome, 1984)

Loffa, Renzium, Justium, Xenorum, Corum, Canesium, Castrum, Latium, and *Quasipetasus.* The age is probably late Carnian or early Norian. The top of the zone is defined by the final occurrence of *Capnodoce,* with other genera appearing close to or at the top of the zone including: *Catoma, Icrioma, Renzium, Xenorum, Corum, Pachus, Canesium, Castrum, Latium, Quasipetasus* and *Xipha.* The top of this zone appears to be missing in eastern Oregon and the *Betraccium* Zone is also missing in eastern Oregon. Blome (1984) subdivided the *Capnodoce* Zone into three subzones: from the base, the *Justium novum* Subzone, the *Xipha striata* Subzone and the *Latium paucum* Subzone.

1a) *Justium novum* Subzone

The base of the *Justium novum* Subzone is defined by the first occurrence of the genera in the *Capnodoce* Zone as decribed above has within the subzone the first occurrences of *Acanthocircus largus, A. laxus, A. supleensis, Catoma concinna, C. geometrica, Icrioma transversa, Justium robustum, Canoptum farawayense, Pachus firmus* and *P. luceletus.* The top of the subzone contains the final occurrences of *Justium* and *Gorgansium acutum* and the apparent final appearances of *Acanthocircus dotti, A. harrisonensis, Renzium webergorum, Betraccium* (?) *incohatum*

1b) *Xipha striata* Subzone

The base of this subzone is defined by the first occurrence of the genus *Xipha* (*Xipha striata, X. pessagnoi*). Other species making a first appearance at or near the base of the subzone include: *Acanthocircus silverensis, Capnuchosphaera deweveri, C. schenki, C. smithorum, Sarla delicata, Icrioma praecipua, Capnodoce insueta, Renzium adversum, Xenorum flexum, Corum regium* and *Latium mundum.* The upper part of the subzone is marked by the final appearance of *Pseudosaturniforma minuta, Latium mundum,* and *Xipha pessagnoi.*

1c) *Latium paucum* Subzone

Latium paucum has its first appearance at the base of this subzone along with *Loffa vesterensis* and *Quasipetasus insolitus.* Other species making their first appearance at or just above the base of the subzone include: *Acanthocircus lupheri, A. macoyensis, A. rotundus, Capnuchosphaera silviesensis, C. sockensis, C. soldierensis, Sarla* (?) *externa, S. longispinosa, Capnodoce fragilis* (also reported to be found in the top of the *Capnodoce* Zone by Carter *pers. comm.* 1991), *C. malaca, C. sinuosa, Gorgansium* sp. A, *Pachus* (?) *indistinctus* and *Triassocampe proprium.* According to Blome (1984) this subzone includes the first occurrence of many species of *Acanthocircus, Capnuchosphaera, Capnodoce,* etc.

2) *Betraccium* Zone

The base of this zone is defined by the first occurrences of *Betraccium* spp., *Pantanellium silberlingi,* and *Pseudoheliodiscus finchi.* The genus *Betraccium* is found throughout this zone and the following species make a final occurrence at an undefined point above:

Pseudoheliodiscus sandspitensis, Pantanellium dawsoni, P. fosteri, Betraccium deweveri, B. inornatum, B. yakounense, Cantalum alium, Ferresium hecatense, F. titulense, Laxtorum hindei and *L. kulensis*. The *Capnodoce* Zone is divided into two subzones, the *Pantanellium silberlingi* Subzone and the *Betraccium deweveri* Subzone.

2a) *Pantanellium silberlingi* Subzone

Basally defined by the base of the *Betraccium* Zone which includes this subzone. The following species have their first or last occurrences within this subzone: *Plafkerium hindei, Pantanellium silberlingi, P. tozeri, Sarla vetusta* and *S. vizcainoensis.* The top of this subzone is marked by the last appearance of *Capnuchosphaera.* Blome (1984) redefined the equivalent Oppel zone of Pessagno (1979) and reduced it to a subzone status.

2b) *Betraccium deweveri* Subzone

Blome (1984) defined the base of this subzone as occurring above the biohorizon containing the last *Capnuchosphaera.* Other species and genera making their first occurrence at or close to the base of this subzone are: *Ferresium, Laxtorum, Pseudoheliodiscus sandspitensis, Pantanellium dawsoni, P. fosteri, P. rothwelli, P. skidegatensis, Betraccium deweveri, B. inornatum, B. maclearni, B. yakounense, Cantalum alium, C. globosum* and *Gorgansium richardsoni.* The top of this subzone is not defined as the stratigraphy of the strata above remain undefined, however, the supposed final occurrence of: *Betraccium, Pseudoheliodiscus sandspitensis, Pantanellium dawsoni, P. fosteri, Betraccium deweveri, B. inornatum, B. yakounense, Cantalum alium, Ferresium hecatense, F. titulense, Laxtorum hiondei* and *L. kulensis* in this area distinguish this subzone.

Blome (1984) produced the only comprehensive study of the Upper Triassic radiolarians from North America. Pessagno (1979) is the only other biostratigraphic scheme for the Upper Triassic of North America utilising radiolarians with a formal division into two Oppel zones. The lack of comparative macrofossil evidence forced Pessagno *et al.* (1979) to only tentatively date his radiolarian assemblages. In Japan, Kishida and Sugano (1982) defined the base of their *Capnodoce anapetes* Zone by the first occurrence of the genus *Capnodoce* and placed this in the mid Carnian, whereas Blome (1984) questionably placed the base of the *Capnodoce* Zone in the late Carnian (with no macrofossil evidence). The top of the *Capnuchosphaera theloides* Zone (Nakaseko and Nishimura, 1979), *Capnodoce anapetes* Zone (Kishida and Sugano, 1982) and *Triassocampe nova* Assemblage (Yao, 1982) occur within the upper part of the middle Norian. This is close to the boundary of the *Capnodoce* Zone as defined by Blome (1984). The base of the *Betraccium* Zone (Blome, 1984) in North America is defined by the first occurrences of several species not found in Japan (*Pantanelliim silberlingi, Betraccium smithi,* *Pseudoheliodiscus finchi*). The genus *Capnuchosphaera* ranges up to the top of the *Pantanellium silberlingi* Subzone in North America, whereas in Japan it appears to be absent in equivalent age strata but occurs commonly in the *Capnuchosphaera theloides* Zone and the *Capnodoce anapetes* Zone below. The equivalent age zones in Japan to the *Betraccium* Zone (North America) are the *Spongosaturnalis multidentatus* Zone (Kishida and Sugano, 1982) and *Canoptum triassicum* Assemblage, neither of which contain *Capnuchosphaera*. Blome (1984) reported that most of the taxa from the *Spongosaturnalis multidentatus* Zone (Kishida and Sugano, 1982) and the *Canoptum triassicum* Assemblage (Yao, 1982) are absent in North America.

Carter (1988, 1990, 1991, 1993) has investigated the Upper Triassic and Lower Jurassic radiolarian faunas of the Queen Charlotte Islands, British Columbia. Well-preserved and diverse radiolarian assemblages have been reported from the Kunga Group with ammonoids, conodonts and pelecypod bivalves, offering a precise, integrated biostratigraphic zonation scheme. The Kunga Group is part of the Wrangellia Terrane, which is mid-palaeolatitude for the most part, but low palaeolatitude aspects of some faunas are indicated (Carter *et al.*, 1989). Carter (1991) described a number of informal assemblages from the late Norian, from the Sandilands Formation, together with assemblages from the older Peril Formation.

The Peril Formation contains lower Carnian ammonoids giving a reliable age constraint for the well-preserved radiolarian assemblage. These assemblages commonly contain abundant and diverse *Capnuchosphaera, Kahlerosphaera, Sarla, Poulpus, Xenorum* and *Xiphotheca* as well as abundant saturnalids and nassellarians. The general faunal composition of this lower Carnian assemblage in the Queen Charlotte Islands matches faunas encountered during this study, especially the presence of *Kahlerosphaera* and numerous saturnalids. Similarities with European assemblages descibed by Kozur and Mostler (1979, 1981) from the lower Carnian of Austria were noted (Carter, 1991 p. 196). Just above this assemblage Carter (1991) reported the rare occurrence of *Justium novum* as an important marker species (see above).. The genus *Kahlerosphaera* appears to change its morphological characteristics with a shortening of the spines in younger forms. Characteristic species at this point include: *Capnuchosphaera concava, C. colemani, C. deweveri, C.* aff.*C. puncta, C. theloides* and *Palaeosaturnalis latiannulatus.* The upper Carnian/lower Norian boundary zone contains more diverse members of the genus *Capnodoce* and more common *Justium novum.* The lower Norian of the Queen

Charlotte Islands is characterised by, amongst others, the following species: *Capnuchosphaera deweveri, C. theloides, C. triassica, Icrioma tetrancistrum, Kahlerosphaera norica, Palaeosaturnalis mocki,* and *Pseudosaturniforma minuta.* The lower part of the lower Norian is marked by *Capnuchosphaera colemani, C. smithorum, Catoma concinna, C. geometrica, Pseudosaturniforma carnica, Spongostylus tortilis, Syringocapsa turgida, Xenorum largum* and *Xiphotheca karpenissionensis.* The middle part of the lower Norian contains *Capnodoce* sp. aff. *C. anapetes, C. crystallina, C. insueta, Icrioma traversa, Latium longulum, Triassocampe propium* and *Vinassaspongus transitus.* The top part of the lower Norian contains *Capnodoce fragilis, Capnuchosphaera* sp. aff. *C. theloides, Palaeosaturnalis lupheri, P. macoyensis, P. rotundus, P. silverensis, P. vigrassi, Renzium adversum, Spongostylus trispinosus, Quasipetasus disertus, Q. insolitus, Veghia sulovensis* and *Harsa* Carter, 1991. Carter (1991) proposed an association of *Capnodoce fragilis, Harsa siscwaiensis* and *Xiphosphaera fistulata* for the upper lower Norian. The middle Norian in the Queen Charlotte Islands still contains the *Capnodoce fragilis, Harsa siscwaiensis, Xiphosphaera fistulata* association around the base but not above. The middle part of the middle Norian contains *Pentactinocarpus sevaticus, Capnuchosphaera, Sarla,* and for the first time examples of *Livarella, Mesosaturnalis* and *Natraglia.* Saturnalids form an important part of the assemblages here together with *Paratriassoastrum, Pseudoheliodiscus, Tetraporobrachia* and *Veghicyclia.* The upper assemblages of the middle Norian as seen in Baja California (Pessagno, 1979) are not observed in the Queen Charlotte Islands. The lower part of the upper Norian contain *Betraccium deweveri, B. maclearni, Gorgansium richardsoni, Livarella densiporata, Norispongus poetschenesis, Pentactinocarpus sevaticus, Pseudohagiastrum* cf. *P. monstruosum, Spongosaturnalis bifidus* and other upper Norian species described in Blome (1984) and is characteristic of the *Betraccium deweveri* Subzone.

Carter (1993) produced an in-depth study of the Rhaetian radiolarians of the Queen Charlotte Islands, British Columbia (Textfig. 6.3, 6.9.4). Distinctive Rhaetian assemblages were reported and elements of these assemblages are observed in the samples recovered in this study. Using the method, Unitary Association (U.A.), which analyses the first and last occurrences of species and so sets maximal groups of mutually coexsisting species, Carter distinguished 27 vertically ordered unitary associations in the Sandilands formation of the Queen Charlotte Islands. These 27 U.A.'s were then placed into three assemblages and four subassemblages. The U.A. method has several advantages when used to define radiolarian biochronology and these include the ability to bring information from several sections into one meaningful data set which gives the maximum occurrence of a species in terms of their coexistence with other taxa. Computer software such as BioGraph enable the user to manipulate large amounts of data to construct stacked sets of unitary associations. The drawback with using U.A. is that consistency of species identification is required in order to achieve meaningful data. Different palaeontologists may identify and classify species differently from others (e.g. saturnalids *sensu* Pessagno or *sensu* De Wever). U. A.'s were not used during this study because sections were generally very small, incomplete and often repeated due to structural complexity of the area. Samples were often in effect spot samples with large distances between each other.

The zones of Carter (1993) are as follows:

Betraccium deweveri Zone in the Queen Charlotte Islands contains various species of the genus *Betraccium,* however, *Betraccium deweveri* appears to have a more restricted range than described in the original definition of this zone. Evidence from elsewhere (Japan and the Philippines) also suggests the more restricted nature of this zone, therefore (Carter, 1993) proposed that the *Betraccium deweveri* Zone is confined to the upper Norian and does not range through the Rhaetian.

Praeparvicingula moniliformis **Zone**

Assemblage 1 contain the following representative taxa: *Archaeocenosphaera* sp. A, *Paronaella bifida, Pseudohagiastrum ? tasuense, Droltus orchardi, Squinabolella ? trispinosa,* and *Livarella densiporata.*

Assemblage 2 is divided into four subassemblages with the following species commonly encountered in all subassemblages: *Fontinella habros, Entactinosphaera ? amphilapes, Paronaella ultrabifida,* and *Praeparvicingula moniliformis.*

> Subassemblage 2a commonly contains: *Fontinella habros, F. inflata, Entactinosphaera ? amphilapes, Paronaella bifida, Pseudohagiastrum ? tasuense,* and *Praeparvicingula moniliformis.*
>
> Subassemblage 2b contains: *Ferresium teekwoonense, Fontinella inflata, F. louisense, Kozurastrum beattiense, Pantanellium* sp. aff. *P. skidegatense, Paronaella ? beattiense, P.ultrabifida, Eptingium ? amoenum, Haeckelcyrtium karcharos, Praeparvicingula moniliformis,* and *Squinabolella desrochersi.*

Subassemblage 2c contains: *Betraccium kennecottense, Paronaella* ? *beatricia, P. ultrabifida* Entaciniid gen. and sp. indet., *Citriduma astreroides, Eptingium* ? *onesimos,* and *Plafkerium fidicularium.*

Subassemblage 2d contains: *Bipedis acrostylus, Citriduma astreroides, Eptingium* ? *onesimos,* and *Laxtorum capitaneum.*

***Globolaxtorum tozeri* Zone**

Assemblage 3 has as its most representative taxa: *Betraccium nodulum, Bistarkum* ? *cylindratum, Ferresium conclusum, F. teekwoonense, Fontinella clara,* Entactiniid gen. and sp. indet., *Citriduma asteroides, Eptingium* ? *onesimos, Globolaxtorum cristatum, G. tozeri, Laxtorum capitaneum. L. porterheadense, Mesosaturnalis acuminatus, Orbiculiforma multibrachiata Plafkerium keloense, Risella ellisensis,* and *R. tieddoensis.*

The above assemblages were correlated with Late Triassic ammonoid zones for North America produced by Tozer (1979) and conodont zonation schemes by Orchard (1991 etc.) (see Textfig. 6.3).

The upper Norian and Rhaetian assemblages in the Queen Charlotte Islands are dominated by species of *Betraccium, Pantanellium, Canoptum, Ferresium, Haeckelicyrtium, Praecitriduma* and *Squinabolella.* Samples from west Timor contain only rare examples of *Betraccium* and *Pantanellium,* which may be due to gaps in the sections. Since at other levels very similar faunal compositions may be observed it is possible that missing assemblages may reflect sampling gaps.

6.3.3 Biostratigraphy of Europe

6.3.4 Introduction

To-date there have been no biostratigraphic zonation schemes defined from Europe utilising Triassic radiolarian faunas. There have, however, been a number of Triassic radiolarian taxonomic studies (Kozur and Mostler 1972, Kozur and Mostler 1978, Kozur and Mostler 1979, Kozur and Mostler 1983, Kozur and Mostler 1984; De Wever *et al.* 1979; De Wever 1984; Donofrio and Mostler 1978; Dumitrica *et al.* 1980, etc.) which are a useful guide for comparison of the generic and species composition of assemblages. It was not until 1979 when De Wever *et al.* published the first of a series of studies examining the Upper Triassic and Lower Jurassic of

Greece, Sicily and Turkey that the biostratigraphic significance of these Mesozoic faunas became apparent.

6.3.5 Late Triassic Biostratigraphy of Europe

De Wever *et al.* (1979) found the following age-significant species within samples from Greece, Sicily and Turkey: *Capnodoce anapetes, C. sarisa, Capnuchosphaera concava, C. lea, C. puncta, C. theloides, C. traissica, C. tricornis, Icrioma tetracistrum, Syringocapsa batodes* and various species of the genus *Poulpus.* De Wever (1985) reported a series of Upper Triassic radiolarians from Hungary which included *Triassocampe* cf. *deweveri, Sarla* sp., *Capnuchosphaera* cf. *lea* and *Poulpus,* all significant as characteristic forms of that age. Kozur and Mostler (1972, 1983, 1990) and De Wever (1984) recognised the significance of saturnalids for the biostratigraphy of the Late Triassic. Their diversity reaches an acme in the end Triassic and they are commonly found worldwide. Three important genera are wholly or partly restricted to Late Triassic age sediments: *Pseudoheliodiscus, Heliosaturnalis* and *Palaeosaturnalis.* These genera have all been described from Austria, Greece, Turkey and elsewhere in Europe.

Kozur and Mostler (1981) described over 140 radiolarian species from Hungary, Austria, Slovakia and Italy. This work is entirely taxonomic, however, it contains species and genera which are typical of the Upper Triassic worldwide including: *Livarella densiporata, Canpotum rhaetica, Triassocampe* spp., *Poulpus* spp., *Pentactinocarpus sevaticus, Vinassaspongus transitus* and *Capnodoce* spp.

6.3.6 Biostratigraphy of New Zealand

6.3.7 Introduction

The New Zealand micro-continent is a fragment of Gondwana which separated from the supercontinent in Late Cretaceous-Early Tertiary time, during the opening of the Tasman Sea (Spörli, 1987). Blome *et al.* (1987) described some well-preserved Upper Triassic radiolarians from Kapiti island, Wellington and Aita and Spörli (1992) reported Upper Triassic radiolarians from Waipapa Terrane which have a Tethyan affinity, while radiolarians of Mid-Jurassic age and younger are non-Tethyan.

6.3.8 Late Triassic Biostratigraphy of New Zealand

Blome *et al.* (1987) described faunas which are upper Norian (coeval to the *Monotis* beds found in the Queen Charlotte Islands. Direct comparisons were made between species found in the Torlesse terrane in New Zealand and specimens recovered from the Queen Charlotte Islands and these include: *Cantalum* sp. aff. *C. globosum, Ferresium* sp. aff. *F. contortum, F.* sp. aff. *F. loganense, Laxtorum* sp. aff. *L. atliense.* Other forms of *Paronaella, Betraccium, Ferresium* and ? *Laxtorum* were recovered and although generally poorly preserved show a resemblance to the radiolarians of the Kunga Formation in the Queen Charlotte Islands. The presence of *Betraccium* and *Cantalum* indicate a late middle to late Norian age when compared with North America, and other samples contained *Ferresium* and *Laxtorum* which are thought to be slightly younger generally, and are restricted to the late Norian of North America. Blome *et al.* (1987) discuss to the possible related paleaogeographic setting of New Zealand (Torlesse terrane) and the Queen Charlotte Islands (Wrangellia). Radiolarian faunas from both areas are similar and could have comparable low-palaeolatitudinal settings, however, poor preservation rules out a definitive conclusion.

6.4.0 Biostratigraphy of Indonesia

6.4.1 Introduction

Hinde (1908) was the first to report Triassic radiolarians from Indonesia. A number of samples from Timor, Roti, Savu, Seram, Sulawesi, Buru and Mangoli were collected and described. The only radiolarians to be extracted from *in situ* sediments were from Roti and Savu, all others were taken from blocks. In some cases *Halobia* and *Daeonella* were found in samples containing the radiolarians and so afforded independent age control. Samples from Timor were taken from the River Moruk in the district of Fiaralang and contained examples of "*Cenosphaera*" and "*Dictyomitra*". As far as the Timor assemblages studied by Hinde (1908) are concerned, the lack of *in situ* sampling brings their validity into question. More carefully collected samples from Roti and Savu are illustrated in the same publication, however, they mainly consist of sectioned specimens with little or no examples of the external ornament. Only a limited number of nassellarians are studied and so comparison to the highly diverse assemblages encountered in this study are of little or no value.

Smith (1983) studied the Mesozoic sediments from the Island of Buton and reported the occurrence of Upper Triassic radiolarian assemblages together with younger Mesozoic radiolarian faunas. Buton is a small island situated off the southeast arm of Sulawesi and is believed to be a fragment of continental crust that was originally part of Palaeozoic Australia (Walley and Moffat, 1988) and so is considered to be a part of the Banda Arc Complex.

As part of the present study and of a separate investigation, concerning Mesozoic microfossils Buton (Rose, 1991), the island was visited and numerous samples taken from Lower Mesozoic sediments. The oldest sediments sampled were from the Winto Formation which was described by Hetzel (1936) (as the Winto Beds) and raised to formation status by Wiryosujono and Hainim (1936). Lithologically the Winto Formation consists of shales, limestones and sandsones. This 'flysch-like' formation contains terrigenous calcareous, graded, cross and ripple bedded sandstones and shales containing plant debris and thin coals and is similar to Triassic sediments reported from other islands in the Banda Arc as well as the from the Northwest Shelf of Australia. A wide variety of microfossils were present in these samples, however, no radiolarians were recovered. Radiolarians were found in younger Mesozoic sediments of Buton and may form part of a future study into the radiolarians of the island.

6.4.2 Late Triassic Biostratigraphy of Timor

Barkham (1993) investigated the sedimentology and structure of the Aitutu and Wai Luli Formations in West Timor. The various palaeontological contents were use to date and give palaeoenvironmental evidence in order to help confirm the sedimentological and structural conclusions of his study. A number of different macro and microfossil groups (ammonites, crinoids, pelecypods, conodonts, ostracods, foraminifera, calcareous nannofossils and radiolaria) were used during Barkham's (1993) and this study (Textfig. 6.9.1). Barkham (1993) stated that the radiolarians recovered from samples in his study were only found in the lower part of the sedimentological cycle (Carnian-Norian) in the Aitutu Formation, however, following re-examination of his radiolarian assemblages and samples it has become apparent that Carnian, Norian, Rhaetian, Sinemurian, Pliensbachian and Toarcian

	Fossil group	Faunal content	Age
Upper part of the cycle	**Ammonites:**	*Anatropites crasseplicatus timorensis*	upper Carnian
	Pelecypods:	*Halobia superba*	upper Carnian
	Crinoids:	*Entrochus ternio*	Sevat
	Conodonts:	*Gondolella polygnathoformis*, *Epigondolella* cf. *primitia*, *Gondolella nodosa*, *Gondolella spatulate*, *Gondolella* cf. *steinbergensis*	Lac and Sevat
	Forams:	*Pseudonodosaria vulgaria multicameratia*, *Frondicularia rhaetica*, *Dentalina* sp., *Nodosaria* sp., *Pseudobolivina torniata* Laginidae	Rhaetian-Liassic
	Ostracods:	*Ptychobairdia kuepperi*, *Anisobairdia gibba*, *A*, *barkhami*, *A.? fastigata*, *Triadohealdia alexandri*, *T. pertruncata*, *T. opisotruncata*, *Torohealdia amphicrassa*, *T. opisthocostata*	Sevat
	Nannofossils:	*Prinsiosphaera triassica*, *Crucirhabdus primulus*, *Crepidolithus crassus*, *Parhabdolithus liassicus liassicus*, *P. liassicu distinctus*, *Biscutum novum.*	Rhaetian-Sinemurian
Middle part of the cycle	**Pelecypods:**	*Halobia zittel*, *?Daeonella tyrolensis*, *Monotis salinaria salinaria* (Sevat)	Carnian (upper Julian)
	Conodonts:	*Epigondolella* sp. indet.	Norian
		Note- This part of the cycle is dominated by pelecypods with greatly reduced microfauna.	
Lower part of the cycle	**Pelecypods:**	*Halobia superba*	upper Carnian
	Conodonts:	*Gondolella polygnathiformis*, *G. hallstadtensis*, *Epigondolella* sp. indet.	Norian (Lac)
	Radiolarians:	The following genera were identified and reported by Barkham (1993): *Capnodoce*, *Capnuchosphaera*, *Canoptum*, *Crucella*, *Betraccium*, *Acanthocircus*, *Paronaella*, *Syringocapsa*, *Orbiculiforma Sarla*, *Xiphotheca*, *Pseudoheliodiscus*	Carnian-Norian

Textfig. 6.9.1 Faunal content of the Aitutu Formation in the River Meto Sections, Soe, West Timor (Same as Textfig. 4.5)

age radiolarians are present.

Dr. E. Kristan-Tollmann accompanied Barkam during fieldwork in 1986 and collected extensively from the sections along the River Meto. A series of formations of the classic East Alps Upper Triassic-Lower Jurassic stages in the Hallstatt facies are reported. Kristan-Tollmann *et al.* (1987) found analogues of the Pötschen, Pedata, Zlambach and Allgäu formations of Europe in the Aitutu and Wai Luli Formations of central Timor. Lithologically and palaeontologically these formations occurring at the western (Europe) and eastern (Timor) ends of Tethys appear almost identical. Fossil groups such as ostracods, calcareous nannofossilils, pelecypod bivalves and Rhyncholites were recovered and documented (Textfig. 6.9.1)

The re-examination of Barkham's samples and subsequent resampling of his sections during this study, using strict methods applicable to micropalaeontological investigation, has made it clear that radiolarians offer the highest biochronological resolution in the Aitutu Formation. Furthermore, the only fossil group commonly occurring throughout the Aitutu and Wai Luli Formations (in shales, limestones, marls and cherts) is radiolaria. Triassic and Jurassic sediments are found on many of the islands which are believed to be fragments of Australian continental crust, now forming the Banda Arc Islands. If these rocks are open marine in origin then it is highly likely that radiolarians will be present to offer an excellent means of biostratigraphic and palaeoenvironmental comparison.

6.4.3 Late Triassic Radiolarian Biostratigraphy of Timor

Four sample sets were used during this study, the first was a series of spot samples collected by Dr. S. T. Barkham. These contained an extremely rich faunal assemblage of mainly Upper Triassic (Carnian-Rhaetian) radiolarians with a few Lower Jurassic (Pliensbachian-Toarcian) radiolarians. A second series of samples were taken by the author during the 1990 field season over a similar area to the samples taken by Barkham (1986). These contained a much more varied set of assemblages covering more of the Early Jurassic (Sinemurian-Toarcian - for a complete radiolarian assemblage breakdown see Range charts 4 and 5). A third set of samples was taken from the island of Buton and were found to be Upper Jurassic and Cretaceous and may form part of a later study. A fourth set of samples was taken from the islands to the east of Timor (Leti, Moa and Babar) where Mesozoic radiolarian cherts and Triassic and Jurassic sediments were reported to be present by Dutch geologists at the beginning of this century. Triassic sediments similar to those of the Winto Formation of Buton were sampled but again found to be almost barren of radiolarians (probably due to the paralic nature of the original environments) appart from some dubious pyritised spherical forms. Middle Jurassic ammonites were recovered from Babar but with no accompanying microfossil evidence.

The oldest radiolarians recovered during this study were Carnian to lower Norian in age (samples SB 223, SB 99 + 101, SB 229) and consist of: *Capnodoce anapetes, C. fragilis, C. insueta, C. kochi, C.* sp. aff. *C. copiosa, Bulbocyrtium* sp. A, *Bipedis* sp. A, *Capnuchosphaera: C. costricta, C. deweveri, C. kapanensis* n. sp., *C. metoensis* n. sp., *C.* sp. aff. *C. theloides, C. triassica,* and *C. tortuosa.* Other characteristic taxa from these oldest samples include: *Homeoparonaella norica, Icrioma* sp. aff. *I. tetracistrum, Kahlerospaera petalouda* n. sp., *K.* sp. aff. *K. longispinosa, Orbiculiforma kylika* n. sp., *O. tethyus, Pachus* sp. aff. *P. longinquus, Palaeosaturnalis latiannulatus, P. raridenticulatus, P. supleensis, Pentactinocarpus aspinosis, P. longispinosis, Poulpus piabyx, Renzium adversum, Sarla longispinosum,Spongostylus carnicus, Syringocapsa batodes, Wuranella carnica, Vinassaspongus transitus* and various species of the genus *Xiphotheca.*

Two samples (SB 239, SB 225) with a narrowly defined range of Carnian-Norian boundary contained some of the radiolarians found in the older samples described above, however, in addition to those, conodonts (*Epigondolella* cf. *primitia*) were present giving slightly more accurate time range.

Sample SB 246, a radiolarite, is considered to be lower lower Norian (Jandianus Zone). This is based upon a rich radiolarian assemblage containing many species incuding the following: *Bulbocyrtium* sp. A, *Cantalum holdsworthi, Capnuchosphaera timorensis, Corum regium, C.* sp. aff. *C. perfectum, Gorgansium* sp. A, *Kahlerosphaera* sp. aff. *K. norica, Pseudohagiastrum* sp. aff. *P. monstruosum, Spongoserrula* ? sp. A, and *Veghia sulovensis.*

Samples SB 233-234 and SB 216-217-218 range through the Norian and contain: *Cantalum holdsworthi, Capnodoce* spp., *Capnuchosphaera metoensis, Ferresium* sp. A, *Orbiculiforma tethyus, Palaeosaturnalis burnensis, Renzium adversum, Syringocapsa batodes,* and *Xipotheca* spp., with SB 216-217-218 also containing

Deflandrecyrtium kozuri n. sp. which is usually found in Rhaetian samples in this study.

Samples SB 231 and SB 232 (radiolarite) are more closely constrained and are restricted to the lower middle Norian. Both samples appear to overlap in terms of their fossil content, however, 232 has more than twice the number of taxa which is likely be a feature of preservation, processing and lithology. Some discrepancies may occur with the appearance of a questionable taxa which appears to be the genus Nassellaria gen. and sp. indet. C (found in the upper Norian and Rhaetian of the Queen Charlotte Islands) and a questionable *Squinabolella* with other older genera such as *Capnuchosphaera*. These occurrences may be the result of contamination which is common in fast-weathering tropical and subtropical climates. Radiolarians common to both samples include: *Canoptum triassicum, Bulbocyrtium* sp. A, *Capnodoce fragilis, Capnuchosphaera kapanensis* n. sp., *C. metoensis* n. sp, *C. timorensis* n. sp, *C.* sp. A, *Ferresium* sp. A, *Kahlerosphaera norica, Karnospongella bispinosa, Orbiculiforma kyklica, O. tethyus, Palaeosaturnalis supleensis, Pentactinocarpus aspinosis, P. longispinosis, Spongostylus carnicus,* Spumellaria gen. and sp. indet. A, *Syringocapsa batodes* and *Vinassaspongus* sp. A. Sample SB 232 contains many more members of the following genera (see Range chart 5 for a complete species list): *Capnodoce, Capnuchosphaera, Gorgansium, Palaeosaturnalis, ?Justium* and *Pseudoheliodiscus.*

Sample 228 contains only a few species, however, these are distinctive and give range of upper middle Norian to upper Norian, and contains the following taxa: *Tetraporobrachia composita, Palaeosaturnalis burnensis* and *Vinassaspongus* sp. A.

Sample SB 213, SB 220 are Rhaetian and SB 224 is upper Norian to Rhaetian and all contain very distinctive assemblages similar to those of Yoshida (1986) and especially Carter (1993) from the Queen Charlotte Islands, British Columbia. SB 213 contains the following species: *Pseudolivarella barkhami* n. gen. and n. sp., *Paronaella leebyi* and *Palaeosaturnalis burnensis.* SB 220 contains the following characteristic genera: *Citraduma* sp. A, *C.* sp. B, *C.* sp. C, *Deflandrecyrtium rhaetica* n. sp., *D. kozuri* n. sp., *?D.* sp. A, *Kozurastrum beatiense, K. sandspitensis, K.* sp. aff. *K. sandspitensis, K.* sp. A, *Livarella densiporata, L.* sp. aff. *L. gifuensis, Paronaella leebyi, P.* sp. aff. *P. bifida, Pentaporobrachia* sp. A, *Pseudohagiastrum longabrachium, Squinabolella? maxima* n. sp., *S.* sp. aff. *S. desrochersi, Tetraporobrachia composita, T. longispinosa, Cantalum holdworthi, C.*

sp. aff. *C. globosum, Bipedis* sp. A, *Pantanellium* sp. A, *Paratriassoastrum* (?) sp. A and *Veghia* sp. aff. *V. goestlingensis.* Sample SB 224 contains the following characteristic taxa: *Betraccium* sp. A, *Citraduma* sp. A, *C.* sp. B, *Kozurastrum beatiense, K. sandspitense, K.* sp. aff. *K. sandspiense, K.* sp. A, *K.* sp. B, *K.* sp. C, *Pseudolivarella barkhami* n. gen. and n. sp., ?*Parahsuum* sp. A, *Paratriassoastrum* sp. aff. *P. omegaense, Paronaella leebyi, P.* sp. aff. *P. bifida, Squinabolella*? *maxima* and *S.*? sp. aff. *S. causia.*

The second sample set was collected during a field season in 1991 and concentrates on a series of tributaries and a small area of the River Meto previously visited by Dr. S. T. Barkham (see Range charts 2 and 5). Sampling was much more closely spaced and wherever possible a number of samples were taken at one location.

Sample Tr 90 069 contains only a few taxa of which *Capnodoce fragilis* is the most characteristic.

Sample Tr 90 061 contains the following characteristic taxa: *Capnuchosphaera metoensis, Capnodoce* sp. A and *Corum regidium.*

Sample Tr 90 056 contains: *Capnodoce* sp. A, *Capnuchosphaera constricta, Homeoparonaella norica, Paronaella* sp. C, *Stylosphaera carnica, Xiphotheca* sp. aff. *X Karpenissonensis.*

Sample Tr 90 051 contains: *Capnodoce fragilis, C.* sp. A. Tr 90 049 contains: *Capnodoce fragilis* and *Xiphotheca* sp. aff. *X karpenissonesis.*

Sample Tr 90 043 contains: *Canoptum* sp. A, *Capnodoce insueta, C. anapetes, C.* sp. aff. *C. copiosa, Capnuchosphaera deweveri, Paronaella* sp. C and *Renzium adversum.* Two other samples from the same section (Tr 90 042 and Tr 90 041) contain similar assemblages which include: *Capnodoce fragilis, C. insueta, C.* sp. A, *Capnuchosphaera constricta, C.* sp. A, *Corum regidium, Icrioma* sp. A, *Natraglia*? sp. A, *Pachus longinquus, Palaeosaturnalis* spp. *Parahsuum* sp. A, *Plafkerium* sp. A, *Pseudoheliodiscus carteri* n. sp, *Stylosphaera carnica* and *Syringocapsa batodes.* These samples are believed to be Carnian-Norian.

The next set of samples include Tr 90 036, Tr 90 035 and Tr 90 034 and are from one section. These samples are upper Norian and Rhaetian, containing the following characteristic species: *Livarella* sp. aff. *L. gifuensis, Pseudolivarella barkhami* n. gen. and n. sp., *Livarella* sp. A, *Betraccium* sp. A, *Kozurastrum* spp., *Paronaella leebyi, ?Globolaxtrorum* sp. aff. *G. tozeri, Canoptum* sp. A, *Pantanellium* sp. aff. *P. fosteri*, *Parahsuum* sp. A, *?Plafkerium keloema* and *Pseudohagiastrum monstruosum.*

The next significant sample is Tr 90 023 and contains examples of: *Livarella densiporata, Pseudolivarella barkhami* n. gen. and n. sp., *?Globolaxtorum sp. aff. G. tozeri, Gorgansium* sp. A, *Pantanellium* sp. A, *Parahsuum* sp. A and *Paronaella* sp. C.

Samples Tr 90 021 and Tr 90 020 are from one small section and contain: *Pseudolivarella barkhami* n. gen. and n. sp., *Livarella* sp. A, *Betraccium deweveri, Kozurastrum* spp. *Gorgansium* sp. A, *Pantanellium* sp. A and *Pseudohagiastrum*? sp. A and is believed to be upper Norian-Rhaetian in age.

Tr 90 007 contains an assemblage unlike any other encountered during this study. *?Eucyrtidellium* sp. A, *?Eucyrtidellium* sp. B, *Pseudolivarella barkhami* n. gen. and n. sp., *Canoptum* sp. A, *Parahsuum* sp. A, *Paronaella* sp. C and *?Tetraporobrachia* sp. A. The presence of the species *Parahsuum* sp. A indicates a range within the Rhaetian, as an identical form from China is figured in Kojima (1989, Pl. 1 figs. 7, 8).

6.4.4 Correlation with other Late Triassic assemblages

6.4.5 Introduction

A range of distinctive Late Triassic radiolarian assemblages are encountered in the sediments of the Aitutu Formation and it is possible to correlate with, and compare and contrast to other assemblages from North America, Japan, Europe and the Philippines (Textfig. 6.3).

6.4.6 Correlation with North America

In North America the base of the *Capnodoce* Zone of Blome (1984) is found in the ? upper Carnian with the *Justium novum* Subzone forming the oldest part of this Zone (Textfig. 6.3). The base of the *Capnodoce* Zone is defined by the first occurrence of the genus *Capnodoce,* and the oldest positively datable samples from this study contain members of the genus *Capnodoce* (*C. anapetes, C.* sp. aff. *C. copiosa, C. insueta, C. kochi* and *C. fragilis*) which commonly occur in the Upper Triassic (Carnian-Norian) of North America. The *Justium novum* Subzone in North America contains *Catoma, Justium, Canoptum, Pachus, Gorgansium, Renzium,* and *Betraccium,* which are present in equivalent age samples from Indonesia, although at species level contents are markedly different and therefore it is possible that this subzone was not sampled or is absent in Timor. Given the structural complexity of the Aitutu Formation in West Timor it is quite possible that the assemblages of the *Justium novum* Subzone are present and were not sampled. The Xipha striata Subzone forms the middle part of the *Capnodoce* Zone and appears to contain a similar assemblage at species as well as generic level in both North America and Indonesia. Commonly occurring species found in both regions include: *Capnuchosphaera deweveri, C. schenki, C. smithorum, Capnodoce insueta, Renzium adversum* and *Corum regium,* however, *Xipha striata* and other members of the genus *Xipha* which occur in North America appear to be absent in Timor. The top of the *Capnodoce* Zone contains the *Latium paucum* Subzone. This subzone contains genera common to both North America and Timor, however, at species level the assemblages have little in common (only *Pachus longinquus* and *Capnodoce fragilis* are found in Indonesian and North American assemblages and these are not necessarily of the same age). Assemblages from Timor lack *Latium* and its representative species occurring at the top of the *Capnodoce* Zone of Blome (1984), although this may have been caused by sampling gaps rather than a true absence.

The *Betraccium* Zone in North America defined by Blome (1984) is an Oppel Zone covering the upper part of the middle Norian to the upper Norian (Upper Norian here includes the Rhaetian, although Carter (1993) illustrates true uppermost Triassic i.e. Rhaetian radiolarian assemblages which appear to differ from the upper Norian of Blome, 1984) and is divided into two subzones. The base is defined by the first appearance of the genus *Betraccium* and not the final appearance of the genus *Capnodoce* from the zone below as the base of the *Betraccium* Zone in eastern Oregon is missing. The oldest subzone is the *Pantanellium silberlingi* Subzone which was introduced by Pessagno (1979) and was emended by Blome (1984) and is characterised by the presence of *Pantanellium silberlingi,* various species of *Sarla, Capnuchosphaera,* and *Pseudoheliodiscus.* There appear to be no species characteristic of this subzone from North America in assemblages recovered from

assemblages

Timor, again bringing into focus the question of true absence from Timor or sampling gaps. Genera making their final appearance in this subzone include *Capnuchosphaera.* The youngest part of the *Betraccium* Zone is the *Betraccium deweveri* Subzone which has a range of upper Norian and its base is defined as being above the final appearance of *Capnuchosphaera.* Assemblages from Timor contain examples of *Betraccium deweveri,* however, they do not contain many other species of *Betraccium, Pantanellium, Ferresium* or *Laxtorum* as seen in North America.

In the study of Carter (1993) (Textfig. 6.3) the *Betraccium deweveri* Zone is the oldest assemblage and is believed to show a more limited range than the *Betraccium deweveri* Subzone of Blome (1984) representing only the upper Norian. The range of the species *Betraccium deweveri* defines the zone as well as the following genera (all of which are common in the Rhaetian): *Ferresium, Fontinella, Loupanus, Canutus?, Canoptum* and *Haliomma?*. Only *Ferresium, Canutus,* and *Canoptum* are present in the upper Norian and Rhaetian of Timor.

Assemblage 1 of Carter (1993) contains *Archaeocenosphaera, Paronaella bifida, Pseudohagiastrum? tasuense, Droltus orchardi, Squinabolella? trispinosa,* and *Livarella densiporata.* In the Upper Triassic of Timor *Paronaella* sp. aff. *P. bifida* and *Livarella densiporata* are present.

Assemblages 2a and 2b of Carter (1993) contain *Fontinella, Paronaella, Praeparvicingula, Entactinosphaera?, Ferresium, Kozurastrum beattiense, Pantanellium, Eptingium ?, Haeckelcyrtium* and *Squinabolella desrochersi,* of which *Kozurastrum beattiense* and *Squinabolella* sp. aff. *S. desrochersi* are present in assemblages from Timor.

Assemblages 2c and 2d in Carter (1993) has no characteristic species in common with those recovered from Timor. Assemblage 3 and samples from Timor only have *Globolaxtorum tozeri* as characteristic species in common.

Distinctive changes in the faunal composition of the upper Norian and Rhaetian radiolarian assemblages take place in the Queen Charlotte Islands, Timor and elsewhere. These changes have relatively few species as common components, however, at generic level with a few notable absences both sets of assemblages appear alike. A lack of greater sample coverage in Indonesia prohibits true testing of

Carters assemblages. The following genera are present in the Queen Charlotte Islands but absent in Timor: *Fontinella, Haliomma*?, *Loupanus, Praeparvicingula, Eptingium*?, *Risella* and *Praecitraduma*. These absences may once again be either the result of true absence or sampling gaps. The affiliation of both sets of samples is borne out by distinctive changes in the genus *Paronaella*, the presence of *Citraduma*, commonly occurring *Kozurastrum, Squinabollela, Livarella*, Nassellaria gen. and sp. indet. B (of Carter) is very similar to *Pseudolivarella barkhami* n. gen. and n. sp. (this study), *Deflandrecyrtium, Pseudohagiastrum* and *Tetraporobrachia*. Further investigation and sampling may well give a more complete overview of the Rhaetian from Timor and increase the similarity between the radiolarians of both areas.

6.4.7 Correlation with Japan

Nakaseko and Nishimura (1979) described three Upper Triassic radiolarian assemblages from the Chichibu and Sambosan groups in central and southwest Japan. These assemblages were from only a handful of samples and therefore cannot be considered particularly reliable, although they give a useful guide to faunal assemblages from this region. The oldest assemblage is the *Capnuchosphaera theloides* assemblage (T type) containing taxa similar to forms from Europe (upper Carnian-lower Norian in De Wever *et al.*, 1979) and Timor (*Capnuchosphaera theloides, C. triassica, Capnodoce anapetes, Syringocapsa* cf. *batodes*). The *Tripocyclia* cf. *acythus* assemblage (R type) has no species which are present in the assemblages recovered from Timor. The youngest assemblage - *Emiluvia* (?) *cochleata* (S type) is also not represented in samples collected from Timor. Yao, Matsuda and Isozaki (1980) Yao, Matsuoka Nakatani (1982) and Kishida and Sugano (1982) indicate that the *Tripocyclia* cf. *acythus* and *Emiluvia* (?) *cochleata* assemblages are older than late Carnian.

Yao, Matsuda and Isosaki (1980) reported four radiolarian assemblages from the Inuyama area of cental Japan. The *Dictyomitrella* sp. A Assemblage is the oldest (Ladinian-early Carnian) with the *Dictyomitrella* sp. B Assemblage above (Carnian-(?) Norian). Poor preservation and transmitted light microscope illustrations make comparison with other assemblages difficult.

Yao (1982) studied Mid to Late Triassic age radiolarians from the Inuyama area of central Japan and produced four distinctive assemblages. The *Triasocampe deweveri*

Assemblage is the oldest (Ladinian) and no equivalent age sediments were analysed in this study. Carnian to middle Norian radiolarians form the *Triassocampe nova* Assemblage; *Capnuchosphaera triassica, C. theloides, Syringocapsa batodes* and *Capnodoce* spp. are found in both Japan and Timor, although *Triassocampe nova* appears to be absent on Timor. The *Canoptum triassicum* Assemblage (upper Norian and Rhaetian) of Yao (1982) has a closer affiliation with radiolarians from both the Queen Charlotte Islands and Timor; *Canoptum triassicum, Dreyericyrtium* sp. A (*Deflandrecyrtium kozuri* n. sp. herein), with similar genera such as *Vinassaspongus, Livarella* and *Palaeosaturnalis* occur in all areas. The youngest assemblage of Yao (1982) is the *Parahsuum simplum* Assemblage which has not been recognised in Timor.

Kishida and Sugano (1982) produced a zonation scheme for the Triassic and Jurassic of southwest Japan. The first zone relevant to this study is the *Capnodoce anapetes* Zone (middle? Carnian to middle Norian) which contains *Capnodoce anapetes,* and *Icrioma tetrancitrum* as found in Timor and characteristic *Capnodoce, Capnuchosphaera* and *Sarla* taxa. Immediately above is the *Spongosaturnalis multidentalus* Zone (believed to be middle Norian-Rhaetian) and contains a rich saturnalid fauna, however, none of these are present in Timor. Carter (1993) suggested that this assemblage is probably middle to upper Norian. The *Pantanellium* sp. B-*Gorgansium* sp. B Zone is changed (in Kishida and Hisada, 1986) to the *Bagotum pseudoerraticum* Zone of Early Jurassic age.

Kishida and Hisada (1985) investigated Mesozoic cherts and mudstones from the Ueno-Mura area of Japan and documented several radiolarian assemblages ranging in age from Late Triassic to Early Jurassic. The *Palaeosaturnalis multidentatus* Assemblage covers the upper Norian and Rhaetian and was believed to be equivalent in age to the *Spongosaturnalis* Assemblage of Kishida and Sugano (1982). Two subassemblages, the *Canoptum* aff. *triassicum* below and the *Canoptum lubricum* above, divide the *Palaeosaturnalis multidentatus* Assemblage. At specific level no taxa were found to be in common between these assemblages and material from Timor.

Kishida and Hisada (1986) recovered Late Carboniferous to Earliest Cretaceous radiolarians from cherts and mudstones from the Kanto Mountains, central Japan. The *Capnodoce anapetes* Assemblage and the renamed *Palaeosaturnalis multidentatus* Assemblage are of interest in relation to the Late Triassic radiolarians of Timor. *Capnuchosphaera triassica* and *Corum* spp. are present in both this zonation (*C. anapetes* Assemblage) and Timor samples. The *Palaeosaturnalis multidentatus* Assemblage contains *Canoptum* sp. aff. *C. triassicum, Palaeosaturnalis* sp. C (*Kozurastrum beattiense* herein) and *Gorgansium* spp., all of which occur in Timor. Carter (1993) believed this assemblage to be correlatable with the *Betraccium deweveri* Zone (upper Norian-middle Rhaetian).

One of the most significant biostratigraphic studies from Japan is Yoshida (1986) in which seven zones are presented (Textfig. 6.9.2, 6.9.4). The oldest, the *Capnuchosphaera* Zone (believed to late Carnian by Yoshida), and contains *Capnuchosphaera* cf. *C. schenki, C. theloides* and members of the genus *Kahlerosphaera* in common with Timor. The *Capnodoce* Zone (late Carnian) above contains the following in Japan and Timor: *Capnodoce fragilis, C.* cf. *C. kochi,* and *C. anapetes* . The *Acanthocircus-Pseudoheliodiscus* Zone is approximately equal to the acme of those two genera and the zone is thought to be as old as mid Norian. At species level there appear to be few common components from Japan and Timor, however, in the middle Norian of Timor (sample SB 231, SB 232) the saturnalids are very abundant and diverse. *Palaeosaturnalis burnensis* from Timor appears very similar to *Acanthocircus* sp. of Yoshida (1986, Pl. 17, fig. 4). The *Betraccium deweveri* Zone has the same limited range in Japan as in the Queen Charlotte Islands and is therefore late Norian only in age. The *Livarella-Canoptum* Zone is significant in that the generic turnover and change can be recognised globally. The base of this zone is characterised by the appearance of forms of *Livarella* and *Dreyericyrtium* ? (*Squinabolella* herein) in Japan and Timor. Other characteristic genera and species common to Japan and Timor include: *Canoptum triassicum,* and *Ferresium* spp. The *Justium* cf. *J. novum* Zone is the youngest zone defined by Yoshida (1986) and is characterised by the first appearance of *Justium* cf. *J. novum, Livarella densiporata* at the base and the first occurrence of the *Parahsuum* group at the top. Carter (1993) could not distinguish the *Livarella-Canoptum* and the *Justium* cf. *J. novum* zones chronostratigraphically.

Mizutani and Kojima (1992) compare selected radiolarians from the Mino terrane of Japan and the Nadanhada terrane in China and illustrate *Parahsuum*(?) sp. A (Pl. 1, fig. 4a, 4b) which is present in one assemblage recovered from Timor (Tr 90 007) and is accompanied by *Livarella* in all three cases.

6.4.8 Correlation with the Philippines

Yeh (1990 and 1992) studied Upper Triassic radiolarians from the Philippines. These samples are geographically closest at present to those found on Timor and so should offer valuable comparative assemblages to study.

Yeh (1990) defined three radiolarian assemblages from the Triassic of Busuanga Island in the North Palawan Block, western Philippines, however, these were from only four samples. The oldest assemblage is the *Busuanga chengi* Assemblage (Ladinian) and was not represented in the present material. The *Trialatus megacornutus* Assemblage (upper Carnian) contains numerous species of *Capnuchosphaera* without the presence of *Capnodoce. Capnuchosphaera crassa, C. triassica* and *Kahlerosphaera* spp. occur in the Philippines and Timor, although in Timor these genera are present with *Capnodoce* spp.. The *Livarella* sp. A Assemblage is the youngest and is believed to be late Norian in age and contains examples of *Livarella, Capnodoce, Betraccium* and *Pseudoheliodiscus.* The following species are present in Busuanga and Timor samples: *Capnuchospheara constricta* (= *C. constricta* herein), *C. contracta* (= *C. constricta* herein), *C. triassica, C. theloides, Gorgansium* sp. A, *Sarla* sp. A (*Vinassaspongus* sp. A herein), *Homeoparonaella* sp. A (resembles *H. norica* herein), *Poulpus piabyx, Pentactinocarpus* sp. B (resembles *P. longispinosis* herein) and Nassellaria indet. gen. B sp. A (*Wuranella carnica* herein) and *Xiphotheca karpenissionensis.*

Yeh (1992) recognised two assemblages from Uson Island (neighbouring Busuanga Island). The upper Norian *Betraccium deweveri* Assemblage is characterised by examples of the genus *Livarella, Canoptum, Pseudoheliodiscus,* Nassellaria indet. gen. C sp. A (*Deflandrecyrtium*? *kozuri* n. sp. herein) , Nassellaria indet. gen. C, sp. B and Spumellaria indet. gen. C. sp. A (*Zhamodjasphaera* sp. A herein). The *Livarella longus* Assemblage (lower Rhaetian) contains several species of *Livarella* of which *L. densiporata* and *L. gifuensis* are present without *Betraccium* spp. in Timor (as in Uson Island). The following species occur in Timor and Uson: *Betraccium deweveri, Gorgansium* sp. A, Unnamed 6-rayed livarellid (*Citraduma* sp. B herein), *Livarella densiporata, L. gifuensis,* (*L.* sp. aff. *L. gifuensis* herein), Nassellaria indet. gen. A, sp. A (*Bipedis* sp. A herein), Nassellaria indet. gen. C, sp. A (*Defladrecyrtium* ? *kozuri* n. sp. herein), Spumellaria indet. gen. C. sp. A (*Zhamodjasphaera* sp. A herein) and *Xiphotheca* sp. A.

6.4.9 Correlation with Europe

In Europe Kozur and Mostler (1972, 1978, 1979, 1981, 1983, 1990), De Wever (1979, 1982, 1984), Lahm (1984) and Dumitrica (1977, 1978, 1982) have all studied Upper Triassic radiolarian assemblages. All these European publications have concentated on taxonomy and have little biostratigraphic content, however, these works remain useful as a guide to assemblage content for comparative analysis.

Kozur and Mostler (1979) is a taxonomic study of Triassic radiolarians from Europe and contains the following species which also in Timor: *Astrocentrus pulcheri, Poulpus piabyx, Zhamojdasphaera latispinosa, Spongostylus carnicus, Capnuchosphaera triassica, C. deweveri, Kahlerosphaera longispinosa, Pseudosaturniforma carnica, Heliosoma carinata* and Nassellaria gen. et spec. inc. (*Karnospongella bispinosa* herein).

Kozur and Mostler (1981) described many new species from Middle and Upper Triassic (Anisian-Rhaetian) strata of Slovakia, Hungary, Austria and Italy of which the following are also found in Timor: *Tirodella goestligensis, Livarella densiporata, Bulbocyrtium reticulatum, Wuranella carnica, Pseudosaturniforma carnica, Poulpus piabyx, Spongostylus carnicus, Paronaella norica* (*Homeoparonaella norica* herein), *Kahlerosphaera aspinosa, Kahlerosphaera norica, Karnospongella bispinosa, Pentactinocarpus sevaticus, Pentactinocarpus aspinosus, Heliosoma? mocki, Palaeosaturnalis raridenticulata, Triarcella sulovensis, Vinassaspongus transitus, Xiphotheca longa and Sulovella constricta* (*Capnuchosphaera constricta* herein). No attempt was made by Kozur And Mostler (1981) to place samples into a biostratigraphic framework, however, it is clear that radiolarians from European Tethys contain many taxa also found in eastern Tethys and elsewhere.

De Wever (1979) studied Upper Triassic (Carnian and Norian) radiolarians from Sicily, Turkey and Greece.The following species occur in his region and Timor: *Capnodoce anapetes, Capnuchosphaera theloides, C. triassica, Icrioma tetracistrum, Orbiculiforma tethyus, Syringocapsa batodes* and *Xiphotheca karpenissionensis.*

6.5.0 Discussion and Conclusions

Sediments of the Aitutu Formation (not including the Sinemurian age sediments of this formation), West Timor yield a range of Late Triassic, Carnian to Rhaetian age radiolarians. A number of distinctive assemblages are revealed which, in terms of their faunal content, compare to a greater or lesser extent with other assemblages from around the world (Textfig. 6.9.2, 6.9.3). Radiolarians from European Tethys and those found in the Philippines, Japan and North America differ in their affinity to assemblages in this study. Study size (number of species recovered) appears to be a significant factor in determining the amount of faunal overlap between regions.

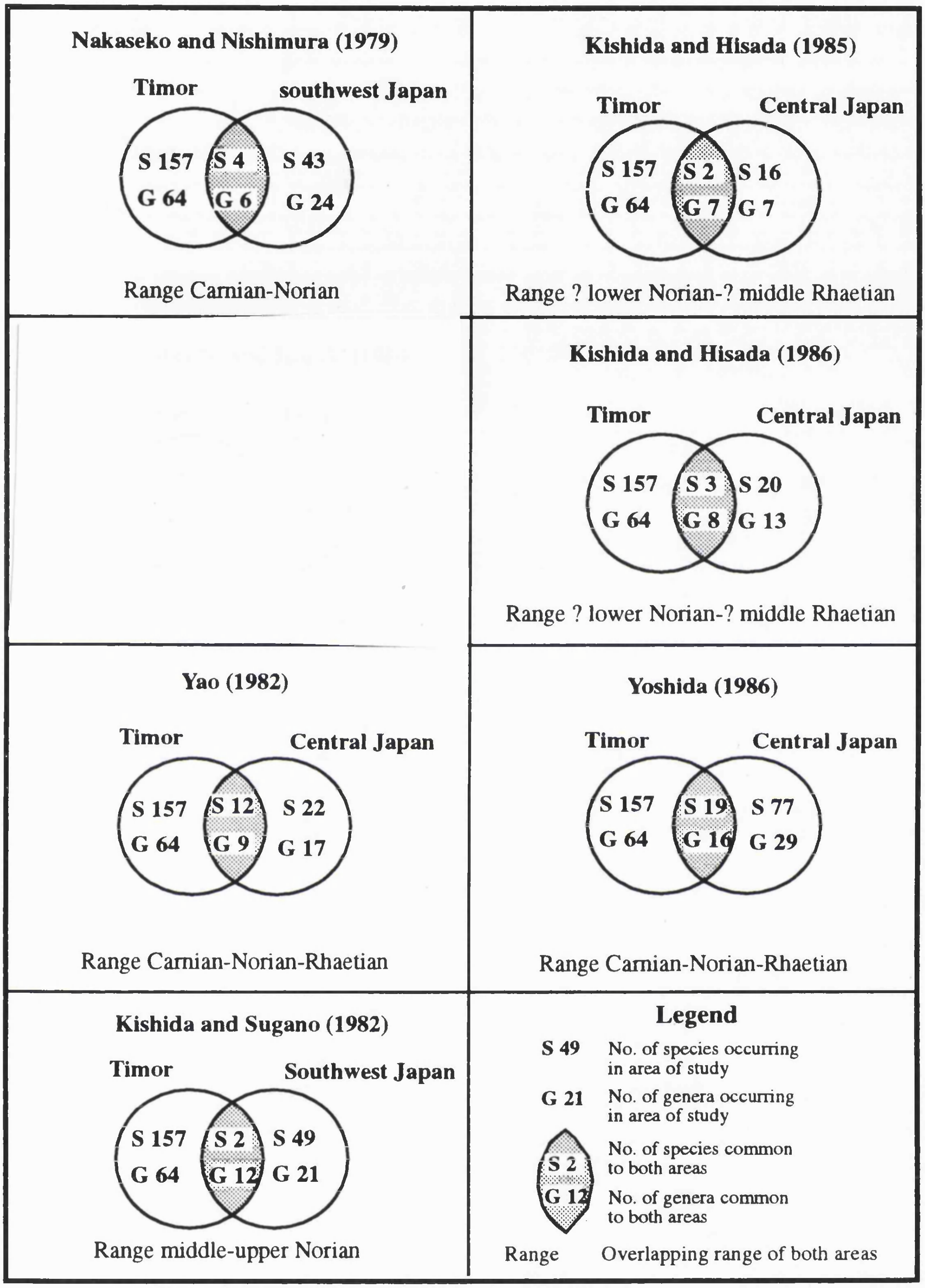
Informally, three assemblages and two subassemblages (Textfig. 6.9.4) may be identified in the radiolarian taxa from Timor and these are as follows:

1) ***Capnodoce-Capnuchosphaera* Assemblage.** This is late Carnian to early Norian in age and is characterised by species of *Capnuchosphaera, Capnodoce* with several examples of *Paleaosaturnalis, Orbiculiforma* and *Renzium* (for a complete species list see Range Chart 5).

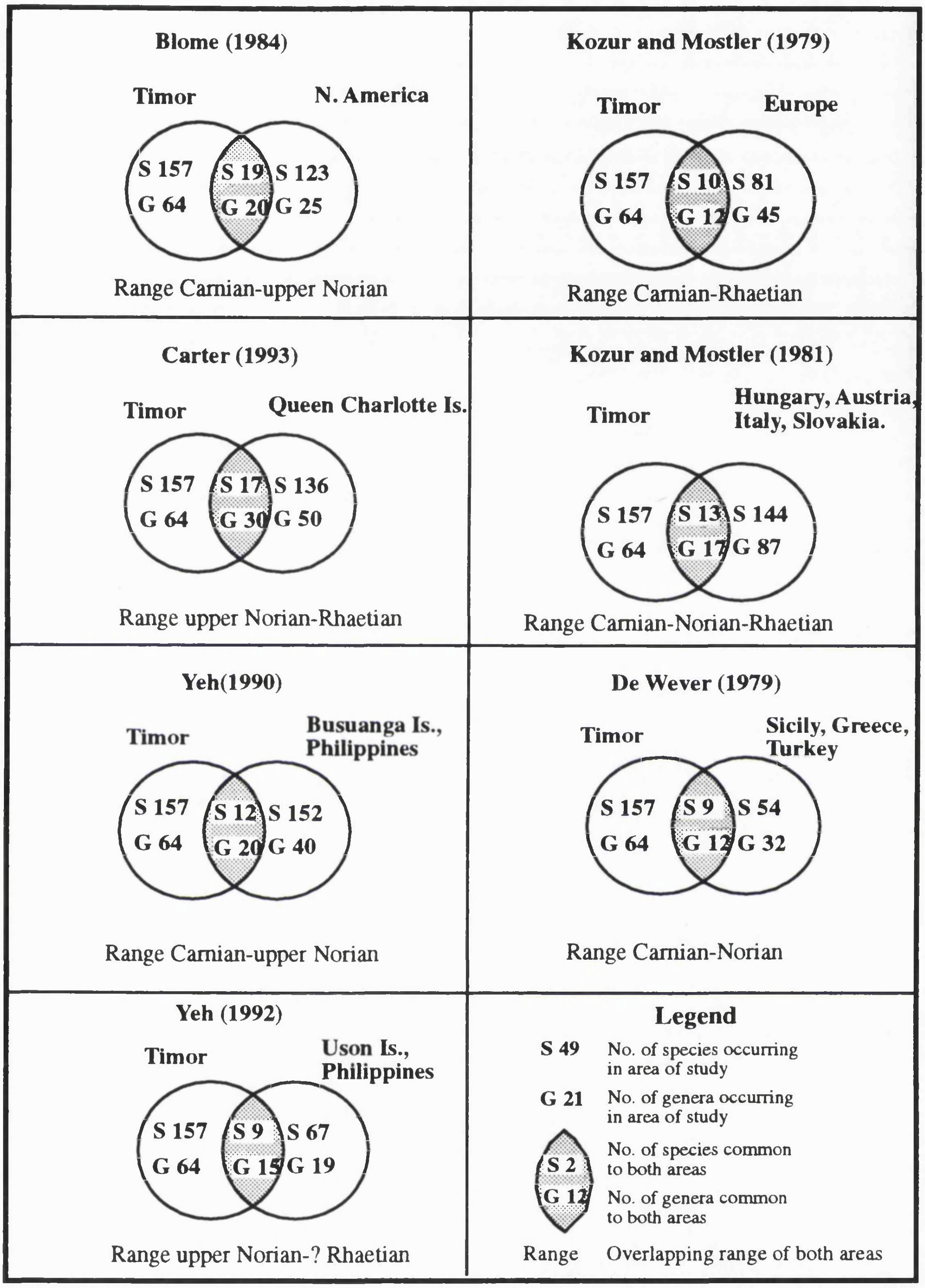
2) ***Palaeosaturnalis* Assemblage.** This is mid Norian in age and contains many of the species observed in the *Capnodoce-Capnuchosphaera* Assemblage, however, in addition this assemblage contains *Gorgansiun,* a greater variety of *Capnuchosphaera* and numerous *Palaeosaturnalius* (for a complete species list see Range Chart 5).

3) ***Kozurastrum-Citraduma* Assemblage** This is divided into the older*Deflandrecyrtium-Livarella* (late Norian) Subassemblage equivalent to the *Betraccium dewever* Zone of (Blome, 1984; Yoshida, 1986, and Carter, 1993) and the younger (late Norian-Rhaetian) ? *Parashuum* sp.A-*Pseudolivarella* n. gen. Subassemblage (for a complete species list see Range Chart 5).

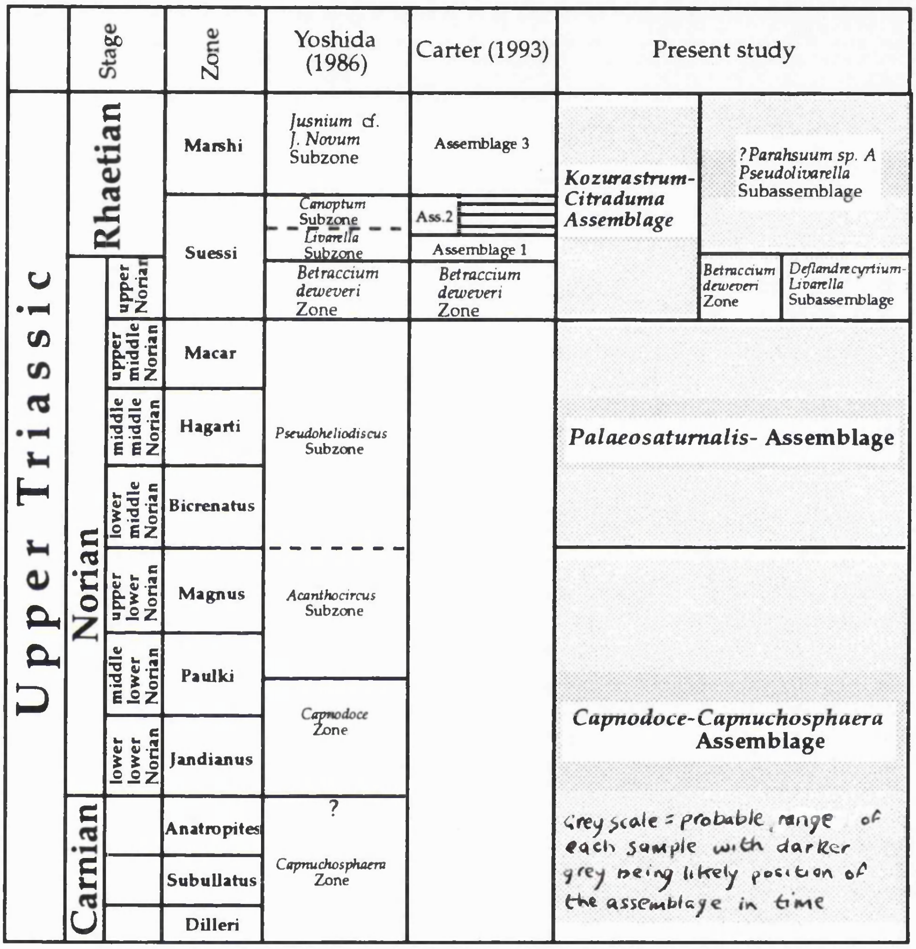
> 3a) ***Deflandrecyrtium-Livarella* Subassemblage (=*Betraccium deweveri* zone).** This is characterised by species of *Citratduma, Deflandrecyrtium, Kozurastrum, Squinabolella, Livarella* and *Betraccium deweveri* (for a complete species list see Range Chart 5).
>
> 3b) **?*Parahsuum* sp. A-*Pseudolivarella*** n. gen. **Subassemblage.** This is characterised by *Citraduma, Kozurastrum, Sqinabolella, ? Parahsuum* sp. A and *Pseudolivarella* n. gen.(for a complete species list see Range Chart 5).



Textfig. 6.9.2 Diagram showing the number of Late Triassic species and genera found in Japan and Timor.



Textfig. 6.9.3 Diagram showing the number of Late Triassic species and genera found in N. America, Europe, Philippines and Timor.



Textfig. 6.9.4 Radiolarian assemblages recovered from Timor, compared to other zonation schemes (for a more complete comparison with other zonation schemes see Textfig. 7.1).

The above assemblages are defined using the abundant and highly diverse radiolarians from samples provided by Dr. S. T. Barkham. These were then tested on the less abundant and diverse assemblages collected by the author and proved to be of use for correlatory purposes.

6.6.0 Worldwide Early Jurassic Radiolarian Biostratigraphy.

In Japan Yao *et al.* (1980, 1982), Yao and Matsuoka (1981) described Lower and Middle Jurassic assemblages. For the purpose of this study the oldest two assemblages (*Parahsuum simplum*, and *Parahsuum* (?) *grande*) are important. Yoshida (1986), Kishida and Hishada (1985, 1986) and Hori (1986, 1990) are significant in detailing the assemblages occurring in the Lower Jurassic of Japan.

In North America Carter (1988) in the Queen Charlotte Islands, British Columbia, Pessagno and Blome (1980) in California, Pessagno and Whalen (1982), Pessagno *et al.* (1987), and Yeh (1987) in Oregon are significant additions to the biostratigraphic study of Lower Jurassic radiolarians.

Studies of the Lower Jurassic of Europe include those of Pessagno and Poisson (1981), Kozur and Mostler (1978), De Wever (1981), however, only a limited number of species occur in the above European studies and the present study.

6.6.1 Early Jurassic Radiolarian Biostratigraphy of Timor

Other fossil groups indicate that the base of the Jurassic is missing in Timor and at no time during this study was any evidence found to confirm the existence of Hettangian age sediments on the island. The oldest confirmed Jurassic is Sinemurian (Tr 90 006) and this age is based on nannofossil evidence as the radiolarians from this sample are poorly preserved and are low in diversity with only long-ranging taxa present - *Canoptum anulatum, Pseudoristola* sp. aff. *P. megalobosa, Spongostaurus* sp. aff. *S. cruciformis.*

The following samples are all believed to be Pliensbachian in age (see Range chart 5): Tr 90 040, Tr 90 039, Tr 90 038, Tr 90 033, Tr 90 019, Tr 90 018, Tr 90 017.2, Tr 90 017.1, Tr 90 017, Tr 90 016, Tr 90 015, Tr 90 012, Tr 90 011, Tr 90 010, Tr

90 009, Tr 90 004, Tr 90 003, Tr 90 002, Tr 90 001. Radiolarians recovered during this study are as follows: *Bistarkum regidium, Canoptum anulatum, Canutus* ? sp. A, *C.* sp. aff. *C. gigantus, Crucella* sp. A, *Crucella sp. B, ?Parahsuum* sp. aff. *P. simplum, P. ovale, ?Hsuum* sp. aff. *mirabundum, Katroma* sp. A, *?Maudia* sp. A, *?M.* sp. B, *Orbiculiforma callosa, O.* sp. A, *Paronaella grahamensis, Praeconocaryoma* sp. A, *P.* sp. B, ? *Pseudoaulophacus* sp. A, *Pseudoristola obesa, P.* sp. aff. *P. megalobosa, P.* sp. A, *Rolumbus* sp. A, *Spongostaurus* sp. aff. *S. cruciformis, Tetratrabs* ? sp. A, *Tricolocapsa* sp. C.

6.6.2 Comparison with other Early Jurassic radiolarians

6.6.3 Introduction

The radiolarians of Early Jurassic age (Sinemurian - Toarcian) recovered during this study are comparable to forms from Japan (Kishida and Sugano, 1982; Yao, 1982; Kishida and Hisada, 1985, 1986; Hori, 1990; etc.), Europe (De Wever, 1981; Pessagno and Poisson, 1981) and western North America (Pessagno and Blome, 1980; Pessagno and Whalen, 1982; Yeh, 1987; Carter, 1988). Radiolarians recovered from the Wai Luli Formation, tend to be poorly preserved and therefore cannot always be accurately identified. In order to assist age assessment, data are used from a study carried out by Finch (1994) of calcareous nannofossils from the samples used in herein (Textfig. 6.9.5).

6.6.4 Comparison with North America

Pessagno and Whalen (1982) concentrated on six multicyrtid families which appeared to be distinctive with short ranges (See Pessagno and Whalen, 1982 p. 114, Textfig. 2). *Canoptum annulatum* (upper Pliensbachian-Toarcian) is found in Turkey and West Timor. The generally poor preservation of the specimens from Timor does not allow for a more complete comparison between the two areas.

Pessagno *et al.* (1986) brought together data concerning Jurassic Nassellariina from the North American geological terranes. Various genera were investigated of which only *Rolumbus* occurs in this study. The lack of similarity in assemblages from North America and Timor, at generic level, probably reflects poor preservation and dissolution during burial and diagenesis.

Period	Jurassic																		Triassic									
Stage/Substage	upper Pliensbach.- lower Toarcian											lower Pliensbach.						Sin.	Norian-Rhaetian									
Nannofossil Zone/Subzone	NJ5											NJ4						NJ2b	P. triassica									
	NJ5b					NJ5a						NJ4b			NJ4a													
Sample No.	Tr 90 016	Tr 90 017	Tr 90 017.2	Tr 90 017.1	Tr 90 018	Tr 90 019	Tr 90 011	Tr 90 012	Tr 90 025	Tr 90 027	Tr 90 001	Tr 90 040	Tr 90 038	Tr 90 009	Tr 90 010	Tr 90 033	Tr 90 004	Tr 90 006	Tr 90 021	Tr 90 034	Tr 90 042	Tr 90 046	Tr 90 051	Tr 90 055	Tr 90 061	Tr 90 070	Tr 90 069	Tr 90 068
ESTIMATED TOTAL ABUNDANCE	A	C	C	C	C	A	C	A	R	R	F	A	A	A	A	A	C	C	R	F	F	R	F	F	F	F	F	F
PRESERVATION / SPECIES	G	G	M	M	G	G	G	G	P	P	P	M	G	G	M	M	M	M	P	F	P	P	P	P	P	P	M	P
Prinsiosphaera triassica																			R	F		R						
Thoracosphaera sp. 1																			R	R	F	R	F	F	F	F	F	F
Thoracosphaera sp. 2																					R					R	F	F
Crepidolithus timorensis																		C										
Crepidolithus crassus	F	F	F		R	F	F	F	R	R	F	C	C	C	C	C	C											
Crepidolithus plienbachensis							F				R	R		F	F	F	F	F										
Crucirhabdus primulus						F	F						R	F	F	F		R										
Mitrolithus elegans							R	?				F	F	F	F	F	F	F										
Mitrolithus elegans var 1													F	R	F	F	F	F										
Mitrolithus jansae					C	F	C				F		R		R		R											
Parhabdolithus liassicus						F																						
Schizosphaerella punctata	?				R	C	C	C	R	R	F	C	C	A	C	C	C	F										
Tubirhabdus patulus	R		?	F	F	?		F	R			R	R	R	F	R	R											
Orthogonoides hamiltoniae		R	F		R																							
Parhabdolithus robustus															R			R										
Similiscutum avitum						R	C	C			F	C	C	C	C	F	R											
Similisctum cruciulus							F	F																				
S. sp. cf. S. precarium	R	R	R																									
Biscutum novum	C	F	F	C	C	C	F	R		R	R																	
Crepidolithus granulatus						R	F	F				F	F	F	R	F	R											
Biscutum finchii				F	R	R																						
Biscutum grande			R	R		R	F	F																				
Lotharingius hauffii	C	C	C	C	A	C	F	R	R	R																		
Lotheringius sagillatus	R	R			?	F			?	?																		
Bussonius prinsii	R					F		R	R																			
Mitrolithus lenticularis						F	C	F			R	F	C	C	F	C	F											
Calyculus indet.	F	R	F	F	R	F	R	R				R		R														
Crepidolithus cavus	F	F	F		F																							

Legend Abundance-A=Abundant, F=Frequent, C=Common, R=Rare
Preservation-G=Good, M=Moderate, P=Poor

Textfig. 6.9.5 Nannofossil assemblage data from the Aitutu and Wai Luli formations, West Timor (after Finch, 1994)

Yeh (1987) studied Lower Jurassic (Pliensbachian-Toarcian) radiolarians from east, central Oregon and illustrated 106 species. *Bistarkum rigidium* and *Orbiculiforma callosa* are the species occurring in western North America and Timor and indicate a range of upper Pliensbachian to lower Toarcian. *Pseudoristola obesa, P.* sp. aff. *P. megalobosa* and *Orbiculiform parvimamma* are common to Timor and Oregon and indicate a range of lower Toarcian.

Carter (1988) studied the Lower and Middle Jurassic radiolarians from the Queen Charlotte Islands. Abundant and well-preserved assemblages from the Queen Charlotte Islands contain the following which occur in Timor: *Praeconocaryomma immodica, Katroma* sp. aff. *K. ninstintsi, Canoptum annulatum, Spongostaurus cruciformis, Paronaella grahamensis, Hsuum* sp. aff. *H. mirabundum, ?Droltus* sp. A occur in both areas and indicate a range of Pliensbachian-Toarcian.

Cordey (1988) studied Triassic and Jurassic radiolarians from Cache Creek, Bridge River and Hozameen Complexes in the Canadian Cordillera. *Praeconocaryomma immodica, P. parvimamma* as well as unassigned forms are present which are similar to those occurring in the Lower Jurassic sediments of Timor.

6.6.5 Comparison with Japan

A number of studies have been carried on the Lower Jurassic radiolarians of Japan (Matsuoka, 1982; Yao, 1982; Kishida and Sugano, 1982; Kishida and Hisada, 1985, Kishida and Hisada, 1986; Matsuoka and Yao, 1986; Hori, 1988, 1990) and other terranes in Asia (Kojima and Mizutani, 1987; Mizutani and Kojima, 1992).

Matsuoka and Yao (1986) proposed a radiolarian zonation for the Jurassic of Japan using eight biohorizons. Only *?Parahsuum* sp. aff. *P. simplum* occurs in the samples recovered from Timor. This marker species, in published literature, appears to exhibit a range of morphologies and different authors assign different morphotype to the same species. This confusion leads to difficulty in accurate assessment of the species content of each sample.

Hori (1990) divided the *Parahsuum simplum* Assemblage zone (of Yao, 1984) into four subzones (I-IV). The base of the zone is defined by the first appearance of *P. simplum.* In Japan Hori (1990) indicated a range of uppermost Triassic to upper

Pliensbachian-Toarcian, which coincides with the age deduced from the radiolarians and calcareous nannofossils from this study.

Kishida and Hisada (1986); Matsuoka and Yao (1986); Yoshida (1986) and Hori (1990) all proposed zonation schemes for the Lower Jurassic of Japan (Textfig. 6.9.6) in which some form of *Parahsuum* zone was indicated. This zone (?*Parahsuum* sp. aff. *P. simplum-P. ovale*) appears in the radiolarian assemblages of Timor studied herein.

6.6.6 Comparison with Europe

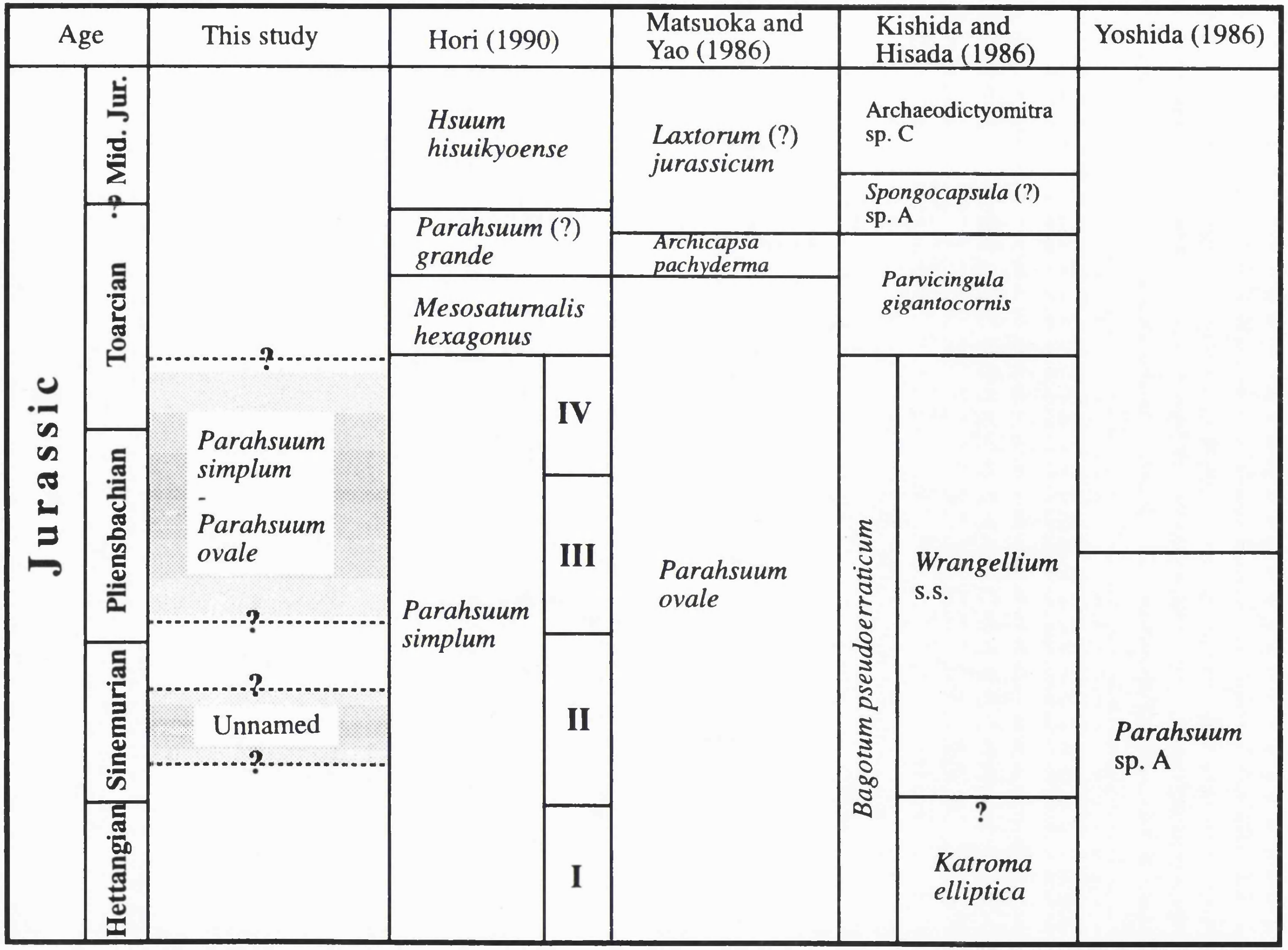
Pessagno and Poisson (1981) investigated Lower Jurassic radiolarians from Turkey. *Praeconocaryomma immodica, P. parvimamma* and *Canoptum annulatum* were described from this area and occur in Timor and elsewhere. Nine significant biohorizons were listed by Pessagno and Poisson (1981 p. 49) of which Biohorizon 4, the first appearance of the genus *Praeconocaryomma* (lower Pliensbachian), is significant as this genus occurs in many Lower Jurassic samples in this study.

De Wever (1981a, 1981b) conducted detailed taxonomic studies of the radiolarians of Lower Jurassic sediments of Turkey. The range of the radiolarians described were not always given although an overall range of upper Sinemurian-and younger is proposed. Many of these well-preserved forms do not occur in the assemblages found during this study which probably reflects an age and/or preservational difference between the two areas.

6.6.7 Discussion and Conclusions

The radiolarians recovered from the Wai Luli Formation of West Timor are Early Jurassic in age and range from Sinemurian to Toarcian. Assemblages from this interval appear to fit into the zonation schemes for Japan (with the presence of the genus *Parahsuum*). Several species from this study are found worldwide (*Canoptum annulatum, Praeconocaryoma immodica, P. parvimamma, Bistarkum regidium*), however, the presence of *Parahsuum* indicates that the Lower Jurassic assemblages of Timor are more closely related to those of Japan than elsewhere (see Textfig. 6.9.6). Lithologically the Aitutu Formation contains some Sinemurian sediments, however, the radiolarians of this age are grouped with 0ther Jurassic forms.

Textfig. 6.9.6 Zonation schemes from Japan compared to assemblages from this study.



Chapter 7

Summary and Conclusions

7.1.0 Introduction

A series of abundant and diverse radiolarian assemblages from the Upper Triassic and Lower Jurassic sediments (Aitutu and Wai Luli formations) of West Timor is described and analysed in this study. Upper Triassic radiolarians provide useful, detailed biostratigraphic data. The Aitutu Formation, West Timor yields a range of Late Triassic (Carnian to Rhaetian) age radiolarians. A number of distinctive assemblages are revealed which, in terms of their faunal content, occur globally. Radiolarians from European Tethys and those found in the Philippines, Japan and North America differ in their affinity to those found on Timor. Study size is likely to affect the faunal overlap from all of these regions.

7.2.0 Late Triassic radiolarian assemblages

Informally, three assemblages and two subassemblages (Textfig. 7.1) are recognised in the radiolarian faunas from Timor and these are as follows:

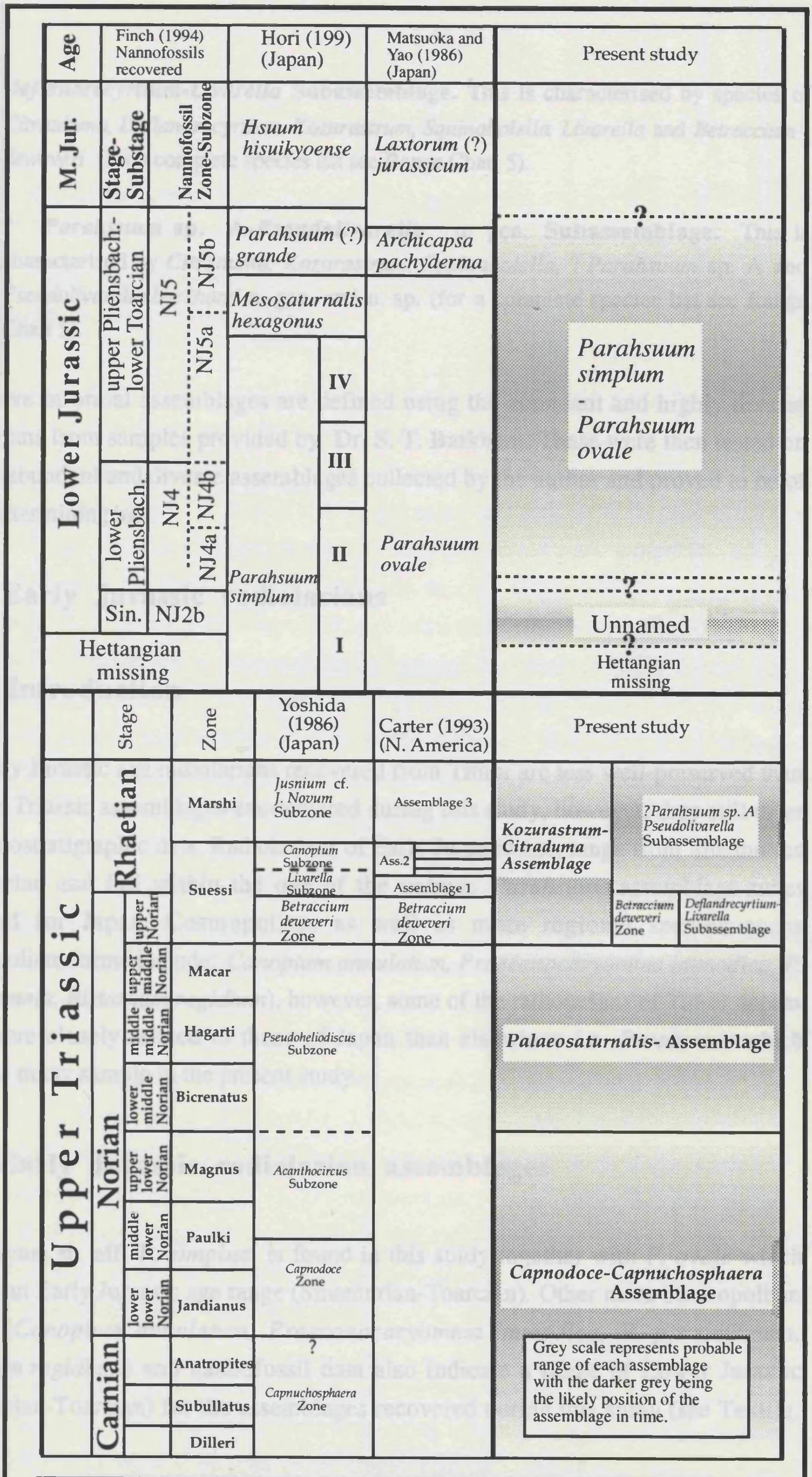
Capnodoce-Capnuchosphaera **Assemblage.** This is upper Carnian to lower Norian in age and is defined by the presence of species of *Capnuchosphaera, Capnodoce* with several examples of *Paleaosaturnalis, Orbiculiforma* and *Renzium* (for a complete species list see Range Chart 5).

Palaeosaturnalis **Assemblage.** This is middle Norian in age and contains many of the species observed in the *Capnodoce-Capnuchosphaera* Assemblage, however, in addition this assemblage contains *Gorgansiun,* a greater variety of *Capnuchosphaera* and numerous *Palaeosaturnalius* (for a complete species list see Range Chart 5).

Kozurastrum-Citraduma **Assemblage** This is divided into the older*Deflandrecyrtium-Livarella* (upper Norian) Subassemblage equivalent to (and containing the zone fossil *Betraccium deweveri*) the *Betraccium deweveri* Zone of (Blome, 1984, Yoshida, 19866, and Carter, 1993) and the younger (? upper Norian-Rhaetian) ? *Parashuum* sp.A-*Pseudolivarella barkhami* n. gen. and n. sp. Subassemblage which is defined by the presence of the above two species (for a complete species list see Range Chart 5).

The assemblages described in this study overlap with several of the species occurring in the zonation schemes of Yoshida (1986) and Carter (1993) (for a full and detailed comparison see paragraph 2 page 141 for Carter (1993), and paragraph 2 page 144 for Yoshida (1986).

The definition of the informal assemblages for the Late Triassic used herein may be taken as the contents (at species level) of each genus name used in the title of each zone. The full list of species is found on range chart 5



Textfig. 7.1 Combined Triassic and Jurassic radiolarian biostratigraphic results with work of Finch (1994) and others.

***Deflandrecyrtium-Livarella* Subassemblage.** This is characterised by species of *Citratduma, Deflandrecyrtium, Kozurastrum, Squinabolella, Livarella* and *Betraccium deweveri* (for a complete species list see Range Chart 5).

? *Parahsuum* sp. A-*Pseudolivarella* n. gen. Subassemblage. This is characterised by *Citraduma, Kozurastrum, Squinabolella, ? Parahsuum* sp. A and *Pseudolivarella barkhami* n. gen. and n. sp. (for a complete species list see Range Chart 5).

The above informal assemblages are defined using the abundant and highly diverse radiolarians from samples provided by Dr. S. T. Barkham. These were then tested on the less abundant and diverse assemblages collected by the author and proved to be of use in determining age.

7.3.0 Early Jurassic radiolarians

7.4.0 Introduction

The Early Jurassic age radiolarians recovered from Timor are less well-preserved than the Late Triassic assemblages encountered during this study, however, they still offer useful biostratigraphic data. Radiolarians of Early Jurassic age, range from Sinemurian to Toarcian and fall within the one of the various *Parahsuum* assemblage zones proposed for Japan. Cosmopolitan as well as more regional species occur (cosmopolitan forms include: *Canoptum annulatum, Praeconocaryomma immodica, P. parvimamma, Bistarkum regidium*), however, some of the radiolarians of Timor appear to be more closely related to those of Japan than elsewhere i.e. *Parahsuum* which occurs in many sample in the present study.

7.5.0 Early Jurassic radiolarian assemblages

?*Parahsuum* sp. aff. *P. simplum* is found in this study together with *P. ovale* which indicate an Early Jurassic age range (Sinemurian-Toarcian). Other more cosmopolitan species (*Canoptum annulatum, Praeconocaryomma immodica, P. parvimamma, Bistarkum regidium*) and nannofossil data also indicate a range of Lower Jurassic (Sinemurian-Toarcian) for the assemblages recovered during this study (see Textfig. 7.1)

7.4.0 Conclusions

In summary, the following conclusions may be made concerning the Mesozoic radiolarians recovered during this study:

1) Diverse and abundant radiolarians from Carnian to Rhaetian (Late Triassic) in age occur in the Aitutu Formation. The radiolarian content indicates that the sediments of the the Aitutu Formation are Rhaetian at the top and upper Carnian at the base of sample collection in this study. The Aitutu is probably as old as Ladinian (data from other fossil groups found, Barkham, 1993) and these data combined give a total age range of Ladinian to Rhaetian. Barkham (1993) believes that the Aitutu contains Sinemurian age sediments, above which a lithological change takes place marking the boundary with the Wai Luli Formation above. The radiolarian content, however, is markedly different in the Sinemurian sediments and specimens are much less well-preserved. This study, using radiolarians, demonstrates a gap in the sequence (Hettangian, see 5 below), above which specimens are differently and less well-preserved although lithostratigraphically still in the Aitutu Formation.

2) Radiolarians are the most reliable microfossil group in terms of occurrence and age significance in the Upper Triassic sediments of the study area. This planktonic group occur in all of the lithological variations occurring in the Aitutu Formation (calcilutites, shales, marls and cherts).

3) Three assemblages and two subassemblages may be observed in the Upper Triassic sediments of West Timor (see Textfig. 7.1 and Range charts 4 and 5). These contain the biostratigraphically significant *Pseudolivarella* n. gen. which is also observed in North America (see Carter, 1993). ?*Parahsuum* sp. A is also important and occurs in China. Endemic or regional variation in the ratio and diversity of some genera (*Palaeosaturnalis, Kozurastrum, Capnodoce, Capnuchosphaera, Citraduma* etc.) appears to occur in the faunas of this study.

4) Other fossil groups such as (see range charts) conodonts and calcareous nannofossils, foraminifera and ostracods support the biostratigraphic data gained from the radiolarian assemblages. Nannofossil data tends to be poor in the Upper Triassic sediments (Aitutu Formation), but much more significant in the Lower Jurassic (Wai Luli Formation).

5) Hettangian (Lower Jurassic) sediments appear to be absent from the studied area and from elsewhere in Timor, as no radiolarians or other fossil groups of this age have been recovered from this study or others conducted in the area.

6) Lower Jurassic radiolarian assemblages have components which are cosmopolitan (e.g. *Canoptum annulatum*) and those which are more endemic, such as the genus *Parahsuum* which occurs in Japan.

7) Although the radiolarian assemblages from the Lower Jurassic sediments (Wai Luli Formation) of West Timor contain poorly-preserved specimens, supporting evidence from the calcareous nannofossil data confirms an age range of ?Sinemurian/Pliensbachian to Toarcian (see Textfig. 6.9.6).

8) The time interval represented by the Wai Luli Formation (gained from the study of the radiolarians herein) is ?Sinemurian/Pliensbachian to Toarcian and no younger.

9) Fossil evidence appears to reveal time gaps (hiatus') in the age of the sediments recovered during this study. The complex structure (with many tectonic boundaries between formations) hinders the true identification of the reasons behind such gaps. These may be the result of genuine hiatus'or of removal during tectonic activity (with formation boundaries forming along less competent layers).

7.5.0 Future research

Potential for a more wide-ranging study of the Mesozoic sediments found on other Banda Arc islands in eastern Indonesia is demonstrated by the abundant and diverse radiolarian assemblages recognised during this study. Reports of similar Mesozoic sedimentary sequences from Seram, Buru, Tanimbar, etc. and their investigation for radiolaria may enhance biostratigraphic resolution further. Many samples are already within the possession of the University of London (and of the author with Cretaceous radiolarians from Buton) and preliminary analysis of these could confirm the presence of a rich source of biostratigraphic information. With further collecting and research (Jurassic and Cretaceous sediments of Timor are being investigated at the present time) the whole of the Mesozoic of these islands could be dealt with and produce workable zonations as demonstrated above.

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References

ABBOTT, M. J. and CHAMALAUN, F. H. (1981): Geochronology of Some Banda Arc volcanics. In: *The Geology and the Tectonics of eastern Indonesia.* A. J. Barber and S. Wryosujono (Eds), GRDC Special Publiction, **2**.

AITA, Y. and SPÖRLI, K. B. (1992): Tectonic and paleobiogeographic significance of radiolarian microfaunas in the Permian to Mesozoic basement rocks of the North Island, New Zealand. *Palaeogeography, Palaeoclimatology, Palaeoecology,* **96**.

ANDERSON, O. R. (1983): *Radiolaria* . Springer-Verlag.

ASHBY, J. N. (1983): Improvements in the technique for the extraction and statistical faunal analysis of radiolarians from Neogene mudstones. *Micropaleontology*, **29**.

AUDLEY-CHARLES, M. G. (1965): The Geology of Portuguese Timor. *Ph.D. Thesis, University of London.*

AUDLEY-CHARLES, M. G. (1968): The Geology of Portuguese Timor. *Memoir Geological Society of London*, **4**.

AUDLEY-CHARLES, M. G. (1981): Geometrical problems and Implications of Large-Scale Overthrusting in the Banda Arc-Australian Margin Collision Zone. In: *Geological Society of London Special Publication,* **9**.

AUDLEY-CHARLES, M. G. (1986): Timor/Tanimbar Trough: The Foreland Basin to the Evolving Banda Orogen In: Foreland Basins, P. A. Allen and P. Honewood (Eds). *International Association Sedimentologists Special Publication,* **8**.

AUDLEY-CHARLES, M. G. (1988): Evolution of the southern margin of Tethys (North Australian region) from early Permian to late Cretaceous. In: Gondwana and Tethys Audley-Charles, M. G. and Hallam, A. (Eds). *Special Publication Geological Society London*, **37**.

AUDLEY-CHARLES, M. G. and CARTER, D. J. (1972): Palaeogeographic Significance of some Aspects of Palaeogene and Early Neogene Stratigraphy and Tectonics of the Timor Sea Region. *Palaeogeography, Palaeoclimatology, Palaeoecology,* **11**.

BARBER, A. J., AUDLEY-CHARLES, M. G. and CARTER, D. J. (1977): Thrust tectonics in Timor. *Journal of Geological Society of Australia*, **24**.

BARBER, A. J., TJOKROSAPOETRO, S., and CHARLTON, T. R. (1986): Wrench faults, shale diapirs, mud volcanoes and melanges in accretionary complexes in Eastern Indonesia. *Bulletin American Association Petroleum Geologists,* **70**.

BARKHAM, S. T. (1986): Preliminary Report on Fieldwork in Central West Timor, October to December 1985. *University of London Consortium for Geological Research in Southeast Asia. Unpublished Report No.* **43**.

BARKHAM, S. T. (1993): The Structure and Stratigraphy of the Permo-Triassic Carbonate Formations of West Timor, Indonesia. *Unpublished Ph.D. Thesis, University of London.*

BAUMGARTNER, P. O. (1980): Late Jurassic Hagiastridae and Patulibrachiidae (Radiolaria)

BAUMGARTNER, P. O. (1981) Methods of mounting radiolaria for the SEM
Spec. Publ. of Interrad III.

from Argolis Peninsula (Peloponnesus, Greece). *Micropaleontology*, **26**.

BEMMELEN, R. W. VAN (1949): The Geology of Indonesia. *The government Printing Office, The Hague.*

BERNOULLI LEMOINE (1980):

BERRY, R. F. (1979): Deformation and Metamorphosis of the Aileu Formation, East Timor. *Ph.D. Thesis, Flinders Univ. South Australia.*

BERRY, R. F. and GRADY, A. E. (1981): The Age of the Major Orogenesis in Timor. In- Geology and Tectonics of Eastern Indonesia, A. J. Barber and S. Wiryosujono (Eds), *GRDC Special Publication,* **2**.

BERRY, R. F. and MCDOUGALL, I. (1986): Interpretation of $^{40}Ar/^{39}Ar$ and K/Ar Dating Evidence from the Aileu Formation, East Timor, Indonesia. *Chemical Geology (Isotope Geoscience Section),* **59.**

BIRD, P. M. (1987): Stratigraphy, sedimentology and structure of the Kekneno Region of West Timor and its relationship with the Northwest Shelf of Australia. *Unpublished Ph. D thesis, University of London.*

BIRD, P. R. and COOK, S. E. (1991): Permo-Triassic successions of the Kekneno arae, West Timor: Implications for Palaeogeographic and basin evolution. *Journal of Southeast Asian Earth Sciences, Special issue* v., **6**.

BLOME, C. D. (1983): Upper Triassic Capnuchosphaeridae and Capnodocinae from eastern Oregon. *Micropaleontology* **29**.

BLOME, C. D. (1984): Upper Triassic Radiolaria and Radiolarian Zonation from western North America. *Bulletin American Paleontol*ogy, **85**.

BLOME, C. D. (1988): Paleogeographic significance of Lower Mesozoic radiolarians from the Brooks Range, Alaska. In: Tailleur, I., and Weimer, P. (Eds.), Alaskan North Slope Geology, **1**: *Society of Economic Paleontologists and Mineralologists, Pacific Section*, Bakersfield, California.

BLOME, C. D., JONES, D. L., MURCHEY, B.L., and LINIECKI, M. (1986): Geologic implications of radiolarian-bearing Paleozoic and Mesozoic rocks from the Blue Mountains province, eastern Oregon. In: Vailler, T. L., and Brooks, H. C. , (Eds.), Geology of the Blue Mountains region of Oregon, Idaho, and Washington-Geological Iplications of Paleozoic and Mesozoic paleontology and biostratigraphy, Blue Mountains Province, Oregon and Idaho: *U. S. Geological Survey Professional Paper*, **1435**.

BLOME, C. D., and REED, K. M. (1986): Triassic and Early Jurassic radiolarian faunas, Brooks Range, Alaska. *U. S. Geological Survey Open-File Report,* **86**.

BLOME, C. D., MOORE, R., SIMES, J. E., and WALTERS, W. A. (1987): Late Triassic Radiolaria from phosphatic concretions in the Torlesse Terrane, Kapiti Island, Wellington. *New Zealand Geological Survey Record,* **18**

BLOME, C. D., REED, K. M., and TAILLEUR, I. L. (1989): Radiolarian Biostratigraphy or the Otuk Formation in and near the National Petroleum Reserve in Alask. *U.S. Geological Survey Professional Paper,* **1399**.

BOLTOVOSKOY, D., KOTZIAN, S. B., and PEDROZO, F.L. (1983): Some new techniques for the preparation and illustration of Polycystina (Radiolaria). *Micopaleontology*, **29**.

BOWN, P. R. (1987): Taxonomy, biostratigraphy and evolution of the Late Triassic-Early Jurassic calcareous nannofossils. *Special Papers in Palaeontology*, **38**.

BRAGIN, N. Ju. (1990): Triassic biostratigraphy of radiolarian deposits in Easterm USSR. In: *Radiolarian Biostratigraphy; Academy of Science of the USSR (Urals department)*, Sverdlosk.

BRAGIN, N. Ju. (1991): Radiolaria and Lower Mesozoic units of the USSR east regions; *Academy of Sciences of the USSR, M.: Nuaka, Transactions*, **469**.

BRALOWER, T. J. *et al.* (1991): Significance of Upper Triassic nannofossils in the Triassic/Jurassic interval. *Les Cahiers de l'University Catholique de Lyon, Serie Sciences*, **3**.

BROUWER, H. A. (1940-1942): Geological Expedition to the Lesser Sunda Islands 1937 under the leadership of H. A. Brouwer Amsterdam, 4 volumes.

BUCH, L. von (1831): EinigeBemerkungen über die Alpen in Baiern. *Abh. preuss. Akad. Wiss.*

CAMPBELL, A. S. (1954): *Protozoa (chiefly Radiolaria and Tintinnia)*.University of Kanasas Press and the Geological Society of America., **61**.

CARTER, D. J. *et al.* (1976): Stratigraphic analysis of island arc-continental margin collision in eastern Indonesia. *Journal of Geological Society of London*, **132**.

CARTER, E. S. (1988): Radiolarian studies in the Queen Charlotte Islands, British Columbia. *Current Research, Part E, Geological Survey of Canada, Paper* **88**-1E.

CARTER, E. S. (1990): New Biostratigraphic Elemnets for Dating Upper Norian Strata from the Sandilands Formation, Queen Charlotte Islands, British Columbia, Canada. *Marine Micropaleontology*, **15**.

CARTER, E. S. (1992): A new phylogenetic lineage (Radiolaria) from the uppermost Triassic of the Queen Charlotte Islands, British Columbia; Fifth North American Paleontologial Convertion, Abstracts and Program, Chicago, Illinois. In: *The Paleontological Society, Special Publication*, **6**.

CARTER, E. S. (1993): Biochronology and Paleontology of Uppermost Triassic (Rhaetian) Radiolarians, Queen Charlotte Islands. *Mémoirs de Géologie (Lausanne)*, **11**.

CARTER, E. S., CAMERON, B. E. B. and SMITH, P. L. (1988): Lower and MIddle Jurassic radiolarian biostratigraphy and systematic paleontology. Queen Charlotte Islands, British Columbia. *Bulletin Geological Survey Canada*, **386**.

CHAMALUAN, F. H. (1977): Paleomagnetic evidence for the relative positions of Timor and Australia in the Permian. *Earth Planet. Science. Lett.*, **34**.

CHAMALAUN, F. H. and GRADY, E. A. (1978): The Tectonic Development of Timor: A New Model and its Implications for Petroleum Exploration. *Australian Petroleum Exploration Association Journal* **18**.

CHAPMAN, S. (1986): *Working witrh a scanning electron microscope*. Lodgemark Press.

CHARLTON, T. R. (1986): The Tectonic Evolution of the Kolbano-Timor Trough

Accretionary Complex, Timor, Indonesia. *Ph. D. Thesis, University of London.*

CHARLTON, T. R. (1987): The Tectonic evolution of the Kolbano-Timor Trough accretionary complex, Timor, Indonesia. *Unpublished PhD Thesis, University of London.*

CHARLTON, T. R. (1989): Stratigraphic correlation across an arc-conyinent collision zone: Timor and the Northwest Shelf. *Australian Journal Earth Sciences,* **36**.

CHARLTON, T. R. (1991): Postcollision extension in arc-continent collision zones, eastern Indonesia. *Geology,* **19**.

CHARLTON, T. R., BARBER, A. J. and BARKHAM, S. T. (1991): The Structural Evolution of the Timor Collision Complex, Eastern Indonesia. *Journal Structural Geology,* **13**, (5).

CHARLTON, T. R. and WALL, D. (1994): New Biostratigraphic Results from the Kolbano Area, Southern West Timor: Implications for the Mesozoic-Tertiary Stratigraphy of Timor. *Journal S. E. Asian Earth Science,* **9**, (in press).

CHENG, Yen-nien (1989): Upper Palaeozoic and Lower Mesozoic radiolaria assemblages from the Busuanga Islands, North Palawan Block, Philippines; In: *Bulletin of the National Museum of Natural Science, Taiwan,* **1.**

COOK, S. E. (1986): Triassic Sediments from East Kekneno, West Timor. *Unpublished Ph.D. thesis University of London.*

CORDEY, F. (1988): Etude des Radiolares Permiens, Triassiques, et Jurassique des Complexes Ophiolitiques de Cache Creek, Bridge River et Hozameen (Colombie Britanique, Canada); implications Paleogeographique et Structurales. *PhD thesis of the university of Pierre and Marie Curie, Paris 6.*

DAGYS, A. S. (1963): Upper Triassic Brachiopods in the south of the USSR. *Akad. Nauk. SSSR Sibir. Otdel.*

DAGYS, A. S. (1988): An alternative interpretation of the Rhaetian. *Albertiana* **7** : (4-6).

DEFLANDRE, G. (1953): *Radiolaires fossiles.* Grassé, P. P., Masson, (Eds) (Paris). In: Traité de Zoologie, **1,** No. 2.

DE METS, C., GORDON, R. G., STEIN, S. and ARGUS, D. F. (1990): Current plate motions. *Geophysics journal int.,* **101**.

De WEVER, P. (1980): A new technique for picking and mounting radiolarians for scanning electron microscopy. *Micropaleontology,* **26**, no. 1.

De WEVER, P. (1981a): Hagiastridae, Patulibrachiidae et Spongodiscidae (Radiolaires Polycystines) du Lias de Turquie. *Revue de Micropaléontologie,* **24**.

De WEVER, P. (1981b): Parasaturnalidae, Pantanellidae et Sponguridae (Radiolares polycystines) du Lias de Turquie.*Revue de Micropaléontologie,* **24**.

De WEVER, P. (1982): Radiolaires du Trias et du Lias de la Téthys (Systématique, Stratigraphie). *Society Géologie Nord.* Publication, Lille, **7**.

De WEVER, P. (1984): Revision des radiolares Mesozoiques de type Saturnalidae, proposition d'une nouvelle classification. *Revue de Micropaléontologie,* **27** (1).

De WEVER, P. SANFILIPPO, A., RIEDEL, W. R. and GRUBER (1979): Triassic radiolarians from Greece, Sicily and Turkey. *Micropaleontology,* **25**.

De SMET, M. E. M., FORTUIN, A. R., TJOKROSAPOETRO, S. and VAN HINTE, L. J. (1989): Late Cenozoic Vertical Movements of Non-Volcanic Islands in the Banda Arc Area. *Proceedings of Snellius-II Symp. Theme: Geology and Geophysics of the Banda Arc and Adjacent Areas, Part I. Netherland Journal Sea Reasearch,* **24**, (2/3).

De SMET, M. E. M., FORTUIN, A. R., TROELESTRA, S. R. VAN MARLE, L. J., KARMINI, M., TJOKROSAPOETRO, S. and HADIWASASTRA, S. (1990): Detection of Collision Related Vertical Movements in the Outer Banda Arc (Timor, Indonesia), using Micropalaeontological Date. *Journal S. E. Asian Earth Sciences,* **4**, (4).

DONOFRIO, D. A. and MOSTLER, H. (1978): Zur Verbreitung der Saturnalidae (Radiolaria) im Mesozoikum der Nordlichen Kalkalpen und Sudalpen. *Geologisch Paläontologische Mitteilungen, Innsbruck,* **7**.

DUMITRICA, P. (1977): Family Eptingiidae n. fam., extinct Nassellaria (Radiolaria) with sagital ring. *D. S. Inst. Geol. Geofiz.*,**64** part 3, paleont.

DUMITRICA, P. (1978): Triassic Palaeoscenidiidae and Entactiniidae from the Vicentinian Alps (Italy) and Eastern Carpathian (Romanian). *D. S. Inst. Geol. Geofiz.*, **64**.

DUMITRICA, P. (1982): Triassic Oertlisponginae (Radiolaria) from East Carpathians and Southern Alps. *D. S. Inst. Geol. Geofiz.*, **67**, part 3, paleont.

DUMITRICA, P., KOZUR, H., and MOSTLER, H. (1980): Contribution to the radiolarian fauna of the Middle Triassic of the Southern Alps. *Geologisch Paläontologische Mitteilungen, Innsbruck,* **10**.

DUNHAM, R. J. (1962): Classification of carbonate rocks according to depositional texture. In Classification of Carbonate Rocks Hann, W. E. (Ed). *American Association Petroleum Geologists Memoir,* **1**.

EXON, N. F., and WILCOX, J. B. (1980): Geology and petroleum potential of Exmouth Plateau area off Western Australia. *Bureau of Mineral Resources, Australia*, Bulletin **199**.

FINCH, J. (1994): Late Triassic and Early Jurassic calcareous nannofossils from Timor. *Unpublished MSc. Report University College London (Department of Geology)*

FITCH, T. J.and Hamilton, W. (1974): Reply to Audley-Charles and Milson (1972). *Journal Geophysical Research,* **79**.

GAGEONNET, R. and LEMOINE, M. (1958): Contribution à la Connaisance de la Géologie de la Province Portugaise du Timor. *Junta Inv. Ultramar Estudos* **48**.

GRADY, E. A. (1975): A reinvestigation of thrusting in E. Timor. *Journal Geological Society Australia,* **22** (2).

GRADY, A. E. and BERRY, R. F. (1977): Some Palaeozoic - Mesozoic stratigraphic - structural relationship in East Timor and their significance in the tectonics of Timor. *Revue de Micropaléontologie,* **24**.

GRUNAU, H. R. (1953): Geologie von Portugiesch Ost-Timor. Eine Kurze Ubersicht. *Eclogae Geologicae Helvetia* **46**.

GRUNAU, H. R. (1956): Zur Geologie von Portugiesch Ost-Timor. *Mitt. Maturf. Ges. Bern.*

DUMITRICA, P. (1972): The hydrofluoiric acid method for the removal of radiolaria from cherts. *D. S. Inst. Geol. Geofiz* **61**, part 3.

13.

GRUNAU, H. R. (1957): Neue Daten zur Geologie von Portugiesch Ost-Timor. *Eclogae Geologicae Helvetia*, **50**.

GÜMBEL, C. W. (1861): Geognostische Beschreibung des Bayerische Alpengebirges und seines Vorlandes. *Gotha* (Justus Perthes).

HAECKEL, E. (1881): Entwurf eines Radiolarien-System auf Grund von Studien der Challenger- Radiolarien; *Jenaische Zeitschrift Für Naturwissenschafter*, **15** (n. ser., 8; 1882). (3).

HAECKEL, E. (1882): Über die Radiolarien der Challenger-Expedition; *Gesellschaft Deutcher Naturforscher und Aerzte, Tageblatt der Versammlung*.

HAILE, N. S. (1987): Time and age in geology: the use of Upper/Lower, late/early in stratigraphic nomenclature. *Marine and Petroleum Geology*, **4**.

HALLAM, A. (1981): The end-Triassic bivalve extinction event. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **35**.

HALLAM, A. (1987): Mesozoic marine organic-rich shales. In Brooks, J. & Fleet, A. J. (eds), Marine Petroleum Source Rocks. *Geological Society Publication*, **26**.

HAMILTON, W. (1979): Tectonics of the Indonesian Region. *U.S. Geological Survey Professional Papers*, **1078**.

HARLAND, W. B., COX, A. V., LLEWELLYN, P. G., PICKTON, C. A. G., SMITH, A. G., and WALTERS, R. (1982): *A Geological Time Scale.* Cambridge Univ. Press.

HATTORI, I. and SAKAMOTO, N. (1989): Geology and Jurassic radiolarians from manganese nodules of the Kanmuriyama-Kanaku area in the Nanjo Massif, Fukui Prefecture central Japan. *Bulletin Fukui Municipal Museum Natural History*, **36**.

HEDBERG, H. D. (Ed) (1976): International stratigraphic guide. A guide to the stratigraphic classification, terminology and procedure, *International subcommission on stratigraphic classification of IUGS commission on stratigraphy*. Wiley-Interscience, New York.

HETZEL, W. H. (1936): Verslag van het onderzoek naar het voorkomen van asfaltgesteenten op het iland Boeton. Verslagen en Mededeelingen betr. Ind Delfst. en hare toepassingen. *Dienst Mijnb. Ned. Indie, Batavia*, **21**.

HORI, R. (1987): Lower Jurassic radiolarian zones; with special reference to radiolarians from the Inuyama area, Central Japan. *Abst. 94th Annual Meet. Geological Society Japan.*

HORI, R. (1990): Lower Jurassic radiolarian zones of SW Japan. *Transactions Proceedings Palaeont. Society Japan, N. S.*, **159**.

HORI, R. and YAO, A. (1988): *Parahsuum* (Radiolaria) from the Lower Jurassic of the Inuyama area, Central Japan. *Journal Geoscience, Osaka City University*, **32**.

IGO, H. and NISHIMURA, H. (1984): The Late Triassic and Early Jurassic radiolarian biostratigrphy in the Karasawa, Kuzuu Town, Tochigi Prefecture (Preliminary report). *Bulletin Tokyo Gakugei Uni*versity, Sec. 4, **36**.

JACOBSON, R. S. *et al.* (1978): Seismic refraction and reflection studies in the Timor-Aru trough system and Australian continental shelf. *Memoirs American Association*

Petroleum Geology, **29**.

JOHNSTON, C. R, and BOWIN, C. (1981): Crtustal Reaction Resulting from the Mid-Pliocene to Recent Continent-Island Arc Collision in the Timor Region. *BMRJ Geology Geophysics*, **6**.

KARIG, D. E., BARBER, A. J., CHARLTON, T. R., KLEMPERER, S. and HUSSONG, D. M. (1987): Nature and Distribution of Deformation Accross the Banda Arc-Australian Collision Zone at Timor. *Geological Society America Bulletin*, **98**, (1).

KATO and IWATA (1989): Radiolarian biostratigraphic study of the pre-tertiary system around the Kamikawa basin, central Hokkaido, Japan. *Journal Faculty Science, Hokkaido University* ser. 4, **22**..

KENYON, C. S. (1974): Stratigraphy and sedimentology of the Late Miocene to Quaternary Deposits of Timor. *Ph. D. Thesis, University of London*.

KISHIDA, Y. and SUGANO, K. (1982): Radiolarian Zonation of Triassic and Jurassic in Outer Side of Southwest Japan. *News Osaka Micropaleaontologists*, **5**.

KISHIDA, Y. and HISADA, K. (1985): Late Triassic to Early Jurassic radiolarian assemblages from the Ueno-mura area, Kanto Mountains, central Japan. *Mem. Osaka Kyoiku Univ*ersity, ser. 3, **34**.

KISHIDA, Y. and HISADA, K. (1986): Radiolarian assemblages of the Sambosan Belt in the western part of the Kanto Mountains, central Japan. *-News Osaka Micropalaeontologists Special Volume*, **7**.

KOJIMA, S. (1989): Mesozoic terrane accretion in Northeast China, Sikhote-Alin and Japan regions. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **69**.

KOJIMA, S. and MIZUTANI, S. (1987): Triassic and Jurassic Radiolaria from the Nadanhada Range, Northeast China. *Transactions Proceedings Palaeontological Society Japan, N. S.*, **148**.

KOZUR, H. (1979): Beitrage zur Erforschung der mesozoischen Radiolarien. Teil III: Oberfamilien Actinommacea Haeckel, 1862, emend. Artiscacea Heackel, 1882, Multiarcusellacea nov. der Spumellaria und triassische Nassellaria. *Geologisch Paläontologische Mitteilungen, Innsbruck*, **8**.

KOZUR, H. AND MOSTLER, H. (1972): Beitrage zur forschung der mesozoischen Radiolarian. Teil I: Revision der Oberfamilie Coccodiscacea Haeckel, 1862, emend. und Beschreibung ihrer triassischen Vertreter. *Geologisch Paläontologische Mitteilungen, Innsbruck*, **2**.

KOZUR, H. AND MOSTLER, H. (1978): Beitrage zur forschung der mesozoischen Radiolarian. Teil II: Oberfamilie Trematodiscacea Haeckel, 1862, emend. und Beschreibung ihrer triassischen Vertreter. *Geologisch Paläontologische Mitteilungen, Innsbruck*, **8**.

KOZUR, H. AND MOSTLER, H. (1979): Beitrage zur forschung der mesozoischen Radiolarian. Teil 3: Die OberfamilieActinommacea Haeckel, 1862, emend.Artiscacea Heackel, 1882 Multiacusellacea nov. der Spumellaria und triassische Nassellaria.*Geologisch Paläontologische Mitteilungen, Innsbruck*, **9**.

KOZUR, H. AND MOSTLER, H. (1981): Beitrage zur forschung der mesozoischen Radiolarian. Teil 4: Thalassosphaera Haeckel, 1862, Hexacastylacea Haeckel, 1882, emend. Petrushevskaya, 1979, Sponguracea Haeckel, 1862 emend. und weitere triassische Lithocycliacea, Trematodiscacea, Actinommacea und Nassellaria. *Geologisch Paläontologische Mitteilungen, Innsbruck*, Sonderband **1**.

KOZUR , H. MOSTLER, H. (1983): The polyphyletic origin and the classification of Mesozoic saturnalids (Radiolaria); *Geologisch Paläontologische Mitteilungen, Innsbruck,* Bd. **13**.

KOZUR , H. MOSTLER, H. (1990): Saturnaliacea Deflandre and some other stratigraphically important Radiolaria from the Hettangian of Lenggries/Isar (Bavaria, Northern Calcareous Alps)*Geologisch Paläontologische Mitteilungen, Innsbruck*, Bd. **17**.

KRISTAN TOLLMANN Von E. (1988): Unexpected communities among the crinoids within the Triassic Tethys and Panthalassa. In BURKE *et al.* (Eds.) *Echinoderm Biology* Balkema, Rotterdam.

KRISTAN TOLLMANN Von E. (1988): Coccolithen aus den Älteren Allgäuschichten (Alpiner Lias, Sinemu) von Timor, Indonesien. *Geol. Paläont. Mitt. Innsbruck,* **15**, pp. 71-83.

KRISTAN TOLLMANN Von E. (1988): Coccolithen aus dem Pliensbach (Älteren Allgäuschichten, Alpiner Lias) von Timor, Indonesien. *Geologisch Paläontologische Mitteilungen, Innsbruck*, **15**.

KRISTAN TOLLMANN Von E., BARKHAM, S. T. and GRUBER, B. (1987): Pötschenschichten, Zlambachmergel (Hallstätter Obertrias) und Liasfleckenmergel in Zentraltimor, nebst ihren Faunenelementen. *Mitteilungen Osterreiche geologie Ges.,* **80**.

KRYSTYN, L. (1980): Triassic conodont localities of the Salzkammergut Region)Northern Calcareous Alps). *Abh. Geol. Bundesanst. Wien,* **35**.

KRYSTYN, L. (1988): Zur Rhaet-Stratigraphie in den Zlambach-Schichten (vorlaeufiger Bericht. *Der Oesterreich, Akademie, Wissenschaft, (Wien),* **1**.

LAHM, B. (1984): Spumellarienfaunen (Radiolaria) aus den mittletriassischen Buhensteiner-Schichten von Recoaro (Norditalien) und den obertriassischn Reiflinge-kalken von Groossreifling (Österreich) - Systematic - Stratigraphic. *Münchner Geowissenschaftliche Abhandlungen* (A) v. **1**. (in German with English and French abstract).

MATSUOKA, A. and YAO, A. (1986): A newly proposed radiolarian zonation for the Jurassic of Japan. *Marine Micropaleontology*., **11**.

MILSOM, J. and AUDLEY-CHARLES, M. G. (1986): Post-collision isostatic readjustment in the Southern Banda Arc. I. Coward, M. P. and Ries, A. C. (eds), *Collision Tectonics, Geological Society Special Publication* No. **19**.

MIZUTANI, S., SHAO, J. and ZHANG, Q. (1990): The Nadanhada Terrane in Relation Tectonics on ContinentAl Margins of East Asia. *Acta geologica Sinica*, . **3**.

MOJSISOVICS, E. von (1869): Über die Gliederung der oberen Triasbildungen der östlichen Alpen. *Journal geology Bundesanst., Wien.* **19**.

MOLENGRAAFF, G. A. F. (1912): On recent crustal movements on the island of Timor and their bearing on the geological history of the East Indian Archipelago. *Proc. Kon. Akad. V. Wetenschi; Amsterdam*, **15**.

MOLENGRAAFF, G. A. F. (1913): Dekbladenbouw in den Timor Archipel.. *Versl. geol. Sectie Geol. Miljnb. Genootschap* **1**.

MOLENGRAAFF, G. A. F. (1914): De Fatoes van Timor. *Versl. geol. Sectie Geol. Miljnb. Genootschap* **1**.

MOLENGRAAFF, G. A. F. (1915): Geografische en Geologische Beschrijving van het Eileng Letti. *Jaarboek Mijmwezen Nederlandsche Oost-Indie* **43**.

MURCHEY, B. (1984): Biostratigraphy and lithostratigraphy of chert in the Franciscan Complex, Marine Headlands, California. In BLAKE, M. C. (ed), Franciscan Geology of Northern California: Pacific Section, S. E. P. M., **43**.

NAKASEKO, K. and NISHIMURA, A. (1979): Upper Triassic Radiolaria from Southwest Japan. *Science Report General Education Osaka Univ*ersity, **28**.

NEUMAYR, M. (1885): Die geographische Verbreitung der Juraformation. *Denkschr. k. Akad. Wiss., Wien., math. inst.*, **50/1**.

OPPEL, A. (1856): Die Juraformations Englands, Frankreichs und südwestlichen Deutchlands. *Jl. Ver. vaterl. Naturk. Württ.* **12**.

PEARSON, D. A. P. (1970): Problems of Rhaetian stratigraphy with special reference to the lower boundary of the stage. *Journal Geological Society of London*, **127**.

PESSAGNO, E. A. (1977a): Upper Jurassic Radiolaria and radiolarian biostratigraphy of the California Coast Ranges. *Micropaleontology*, **23**.

PESSAGNO, E, A. (1977b): Lower Cretaceous radiolarian biostratigraphy of the Great Valley Sequence and Franciscan Complex, California Coast Ranges. In: *Cushman Foundation for Foraminiferal Research, special Publication.*

PESSAGNO, E. A. and NEWPORT, R. L. (1972): A technique for extracting Radiolaria from radiolarian cherts. *Micropaleontology*, **18**.

PESSAGNO, E. A., FINCH, W., ABBOT (1979): Upper Triassic Radiolaria from the San Hipolito Formation, Baja California. *Micropaleontology*, **25**.

PESSAGNO, E. A., and BLOME, C. D. (1980): Upper Jurassic Pantanelliinae from California, Oregon and British Columbia. *Micropaleontology*, **26**.

PESSAGNO, E. A. and WHALEN, P. A. (1982): Lower and Middle Jurassic Radiolaria (multicyrtid Nassellariina) from California, east-central Oregon and the Queen Charlotte Islands, British Columbia. *Micropaleontology*, **28**.

PESSAGNO, E. A., WHALEN, P. A., YEH, K.-Y. (1986): Jurassic Nassellariina (Radiolaria) from the North American Terranes. *Bulletins of American Paleontology*, **91**.

PESSAGNO, E. A., SIX, W. M., and YANG, Q. (1989): The Xiphostylidae Haeckel and Parvicingulidae, n. fam., (Radiolaria) from the North American Jurassic. *Micropaleontology*, **35**.

PETRUSHEVSKAYA, M. G. (1967): Radiolyarii otryadov Spumellaria i Nassellaria antarkticheskoi oblasti. In: *Issledovaniya Fauny Morei,* **4** (12), Resultaty Biologicheskikh Issledovanii Sovetskoi Antarkticheskoi Ekspeditsii 1955-1958, 3 Andriyashev, A. and Ushakov, P. (eds), Izdatelstvo Nauka, Leningrad.

PETRUSHEVSKAYA, M. G. (1971): *On the natural system of polycystine Radiolaria (Class Sarcodina).* In: Proceedings II Planktonic Conference, Roma, 1970, Farinacci, A. (ed), pp. 981-2, Technoscienza, Rome.

POPOV, Yu. N. (1961): The Rhaetian of north-east Asia. *So. Geol.* **3**.

PRICE, N. J. and AUDLEY-CHARLES, M. G. (1983): Plate Rupture by Hydraulic Fracture Resulting in Overthrusting. *Nature* **306**.

QUILTY, P. G. (1980):Tertiary Foraminiferida and stratigraphy, northern Exmouth Plateau, Western Australia. *BMR Journal of Australian Geology & Geophysics,* **5**.

RICHARDSON, A. N. (1993): Lithospheric structure and dynamics of the Banda Arc, eastern Indonesia. *Unpublished PhD Thesis of the University of London.*

RIEDEL, W. R. (1971): Systematic classification of polycystine Radiolaria. In Funnel, B. and Riedel W. R. (eds), *The micropalaeontology of the ocaens*, Cambridge University Press.

RIEDEL, W. R. (1967): Subclass Radiolaria. In: *The Fossil Record*, Harland, W. R. (ed), Geological Society of London.

ROSIDI, K, *et al.* (1979): Geological map of the Kupang-Atambua Quadrangles, Timor. 1: 250, 000.*Geologogical Research and Development Centre, Bandung, Indonesia.*

RÜST, H. (1885): Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Jura; *Palaeontographica,* **31**.

SANFILIPPO, A. and RIEDEL, W. R. (1985): Cretaceous Radiolaria. In BOLLI, H. M. *et al.* (eds): *Plankton Stratigraphy*, . Cambridge University Press.

SLAVIN, V. I. (1961): Problèmes généraux de la subdivision du Trias supérieur et inférieur dans la region du géosynclinal alpin. *Ann. Inst. geol. Hungary,* **49**.

SLAVIN, V. I. (1963): Au sujet Rhétien. Colloque sur le Trias de la France et des régions limitrophes. Montpellier 1961. *C.r. Congress Socs. sav. Paris Sect. Sdi. (Mém. Bur. géol. min.)* **15**.

SMITH, R. B. (1985): Sedimentology and Tectonics of a Miocene collision complex and overlying late orogenic clastic strait, Buton Island, eastern Indonesia. *Unpubished PhD. thesis, University of California, Santa Cruz.*

STACKELBERG, U. von *et al.* (1980): Geology of the Exmouth and Wallaby Plateaus off northwest Australia: sampling of seismic sequences. *BMR Journal of Australian Geology Geophysics*, **5**.

SUESS, E. (1893): Are great oceans depths permanent ?*Nat. Sci..*, **2**.

TAIJIKA & IWATA (1990): Palaeogene melange of the Northern Hidaka belt-geology and radiolarian age of the Kamiokoppe Formation. *Rep. Hokkai-Gakuen University* **66**,

TAPPAN, H. and LOEBLICH, A. R. Jr. (1973): Evolution of the ocean plankton. *Earth Science Revs*, **9**.

TEICHERT, C. (1939): The Mesozoic transgressions in Western Australia. *Australian Journal* *of Science*, **2**.

TJOKROSAPOETRO, S. (1978): Holocene tectonics on Timor Island. *Bull. geol. Soc. Am.* **65**, pp. 143-64.

TOBING (1989): The Geology of East Timor. Unpublished *PhD. Thesis, University of London.*

TOZER, E. T. (1979): Latest Triassic ammonoid faunas and biochronology, Western Canada. *Geological Suvey of Canada, paper* **79**-1b.

TOZER, E. T. (1980): Latest Triassic (Upper Norian) ammonoid and *Monotis* faunas and correlations.*Riv. Ital. Paleontol.*, **85**.

TOZER, E. T. (1984): The Trias and its Ammonoids: the Evolution of a Time Scale. *Geological Sirvey of Canada, Miscellaneous Report,* **35**.

TUCHOV, I. I. (1964): Rhaetian Stage problem and the lower boundary of the Jurassic System. *-Intl. geol. Congr. Colloque du Jurassic. Luxembourg, 1962. Comptes et Mémoirs.*

WENSINI (1990):

WIEDMANN, J. *et al.* (1979): Ueber Umfang und stallung des Rhaet. *Newsletters on Stratigraphy,* **2**.

WIRYOSUJONO, S. and Hainim, J. A. (1978): Cainozoic sedimentation in Buton Island. In Wiryosujono, S. and Sudradjat, A. (eds.) *Regional conference on the geology and mineral resources of Southeast Asia, Jakarta, Indonesia, Aug. 1975, Indonesian Association Geologists.*

URQUHART, E. (1992): Campanian radiolarians from the Cyprus and the Atlantic. *Unpublished PhD thesis University of London.*

YAO, A. (1972): Radiolarian fauna from the Mino belt in the northern part of the Inuyama area, Central Japan. Part I: Spongosaturnalids. *Journal. Geoscience, Osaka City Univ*ersity, **15**.

YAO, A. (1982): Middle Triassic to Early Jurassic radiolarians from the Inuyama area, Central Japan. *Journal of Geosciences, Osaka City University*, **25**.

YAO, A. (1991): Triassic and Jurassic Radiolarians. In: (ed. Mizutani, M.) *Radiolarian Biostratigraphy and its International correlation. Report of Co-operative Resaerch (A).*

YAO, A., MATSUDA, T. and ISOZAKI, Y. (1980): Triassic and Jurassic radiolarians from the Inuyama area, central Japan. *Journal Geosciences, Osaka City Univ*ersity, **23**.

YAO, A., MATSUOKA, A. and NAKATANI, T. (1982): Triassic and Jurassic radiolarian assemblages in Southwest Japan. *News Osaka Micropalaeontologists, Special Publication*, **5**.

YEH, Kuei-Yu (1987): Taxonomic studies of Lower Jurassic Radiolaria from East-Central Oregon.*National Museum of Natural Sciences, Taiwan, Special Publication* , **2**.

YEH, Kuei-Yu (1990): Taxonomic studies of Triassic Radiolaria from Busuanga Island, Philippines. *Bulletin of the National Museum of Natural Science, Taiwan*, **2**.

YEH, Kuei-Yu (1992): Triassic Radiolaria from Uson Island, Philippine. *Bulletin of the National Museum of Natural Science, Taiwan,* **3**.

YOSHIDA, H. (1986): Upper Triassic to Lower Jurassic radiolarian biostratigraphy in Kagamigahara City, Gifu Prefecture, central Japan. *Journal of Earth Sciences, Nagoya University*, **34**.

ZAPFE, H. (1960): Utersuchungen im obertriadischen Riff des Gosaukammes (Dachsteingebiet, Oberösterreich). 8. Fragen und Befunde von allgemeiner Bedeutung für die Biostratigraphie der alpienen Obertras. *Verh. geol. Bundesanst., Wien*, **70**.

Appendix 1

Systematic Palaeontology of Late Triassic Radiolarians

A.1.1.0 Introduction

A number of radiolarian groups have problematic taxonomy. These are reviewed in the text below with an explanation of why certain taxonomic schemes are prefered to others. Saturnalids, hagiastrids, patulibracchiids and livarellids are amongst the forms which have more than one interpretation and are therefore assessed.

A.1.1.1 Taxonomy of Mesozoic saturnalids, a literature review

A.1.1.2 Introduction

Saturnalids form an important constituent of the Triassic radiolarian assemblages recovered during this study, and therefore a review of the literature previously published was undertaken in order explain the reasons for adopting a particular taxonomic scheme for this group. The term 'saturnalid' is used for all Radiolaria with a saturnalid ring, that is an equatorial ring surrounding the central shell, attached to the shell by two or more spines, regardless of their phylogenetic relationship. Mesozoic saturnalids are a polyphyletic group related partly to the Spumellaria Ehrenberg, 1875 and partly to the Entactinaria Kozur and Mostler, 1982 (Kozur and Mostler, 1983) This diverse group of radiolarians first appears in the upper Ladinian (Middle Triassic) and reaches an acme in the Upper Triassic where, biostratigraphically significant, short-ranging forms occur. This acme ends in the upper part of the Lower Jurassic where younger Mesozoic radiolarian groups became dominant.

A.1.1.3 Published literature

Kozur and Mostler (1972) were the first to describe and publish Mesozoic examples of saturnalid radiolarians. Their rich and highly diverse material from the Upper Triassic of Austria represents one of only a few well-documented assemblages of the group from this period. In their publication, Kozur and Mostler (1972) emended the

Coccodiscacea Haeckel 1862. This superfamily contained the families: Coccodiscacae Haeckel 1862, Astracturidae Haeckel 1882, Heliodiscidae Haeckel 1882, and Saturnalidae Deflandre 1953 (Kozur and Mostler treated the Parasaturnalidae as a subfamily of the Saturnalidae and so divided the Saturnalidae into two subfamilies), to which Kozur and Mostler added the Veghicyclidae Kozur and Mostler, 1972. The authors also discussed the idea that the Saturnalidae and Veghicyclidae were descended from the Heliodiscidae. In total, three new families and subfamilies, 16 new genera and subgenera and 43 new species were described by Kozur and Mostler (1972).

Yao (1972) reported and illustrated an excellent assemblage of spongosaturnalids from the Mesozoic Mino Belt, Inuyama Area, central Japan. Fifteen new species of *Spongosaturnalis* were described, of which four were not specifically named. Yao also suggested that the differences in the cross-section of the ring might be an important taxonomic feature and placed various species in a tentative dendrogram of 'probable lines of development' showing, for instance, that forms with bifurcated spines on the outer edge of the ring probably developed into forms with a second sagittal ring. Some confusion arises as to the age of these saturnalids as several resemble specimens recovered from California which are restricted to the Cretaceous. Other fossil groups have been used to propose various ages for this Japanese material, from the Palaeozoic (forams) to the Late Triassic (conodonts) and Jurassic (ammonites). Some saturnalids do resemble those commonly found in the Late Triassic worldwide which only adds to the 'range' problem. Nothing recovered in the present study from eastern Indonesia has the narrow 'Cretaceous-type' sagittal ring illustrated by Yao (1972, Pl. 1-11).

Tikhomirova (1975) descibed the genus *Saturnosphaera* which has a serrated ring and is representated by the two species: *S. gracilis* and *S. acifer* from the Late Triassic and Early Jurassic of the Far East.

Pessagno (1977) elevated a group of taxa based on the genus *Acanthocircus* (Squinabol, 1903) to family level forming the Acanthocircidae. He distinguishes the Acanthocircidae from the Saturnalidae by:

(1) having a spongy cortical shell, consisting of concentric layers of irregular pore frames.
(2) having one or more latticed medullary shells.

Figured specimens in Pessagno's (1977) paper have no auxiliary spines and exhibit a concave indentation around the outer edge of the sagittal ring at the point of attachment to the polar spines.

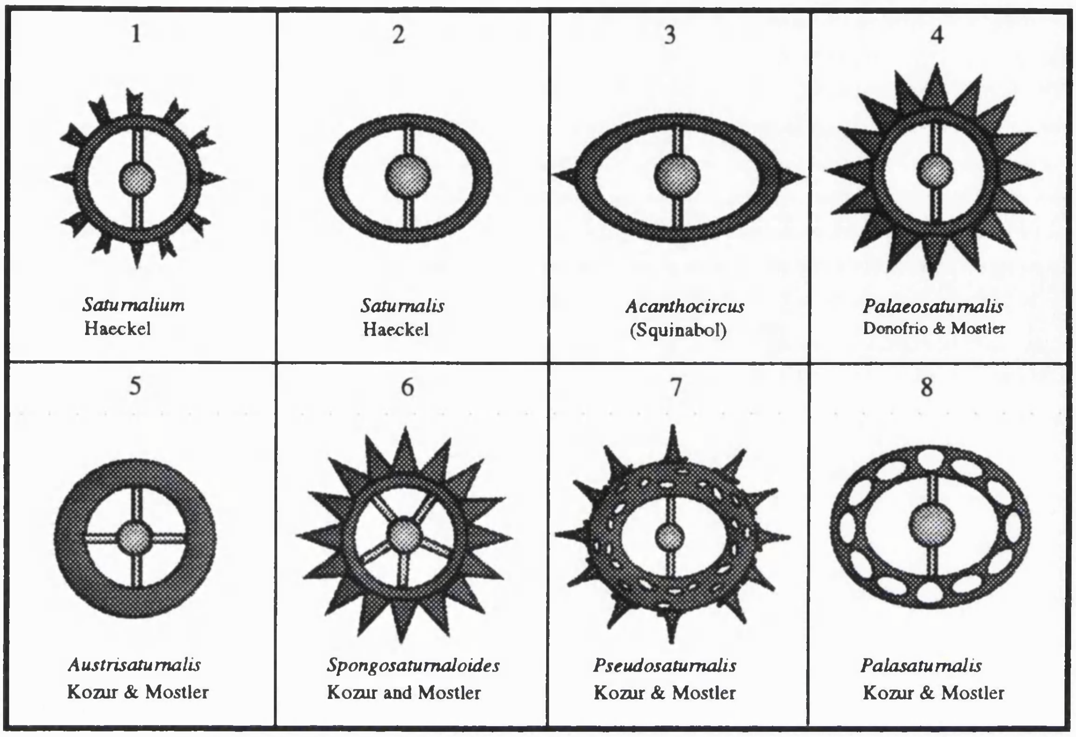
Donofrio and Mostler (1978) recovered the earliest representatives of the Saturnalidae from the Triassic in the Austrian Alps and discussed the stratigraphic value of all Saturnalidae occurring in their samples recovered (Textfig. A.1.1). Donofrio and Mostler (1978, p. 33) figured two different types of *Palaeosaturnalis* one with and one without auxiliary spines, the latter has polar spines which do not align with any axial spines.

Kozur (1979) introduced the genus *Pessagnosaturnalis* which has two polar spines, and auxiliary spines, unlike *Spongosaturnalis triassicus* Kozur and Mostler, 1972 which has two polar spines only.

In 1979, Pessagno *et al.* radically emended the Family Parasaturnalidae Kozur and Mostler, 1972 (see Textfig. A.1.2) for Pessagno *et al.* classification table) in which the Acanthocircidae Pessagno (1977a, 1977b) was changed to a junior synonym of Parasaturnalidae. Pessagno *et al.* (1979, p. 166-7) elevated the Parasaturnalidae to family status and separated it from the Saturnalidae for the following reasons:

> 1) Members of the Parasaturnalidae have spongy cortical shell comprising of concentric layers of irregular pore frames and one or more latticed shell(s), ranging from the Upper Triassic (Carnian? Norian) to Upper Cretaceous.
> 2) Saturnalidae Deflandre, 1953 have latticed shells throughout their ontogeny and range from the Upper Cretaceous onward. Only the genera *Saturnalis* and *Saturnalium* remained in the revised version of the group, all other genera were transferred to the Parasaturnalidae. Three of the seven genera and subgenera which Kozur and Mostler included in the Heliodiscidae were reassigned to the Parasaturnalidae (*Pseudoheliodiscus*, Kozur and Mostler, 1972, *Praeheliodiscus*, Kozur and Mostler, 1972 and *Heliosaturnalis*, Kozur and Mostler, 1972). *Praeheliosaturnalis* is neither a heliodiscid or parasaturnalid.

Pessagno *et al.* (1979, p. 168) remarked that the classification of Kozur and Mostler was highly artificial, based more on test shape than on construction and hoped that their own classification, based primarily on test construction, would be more natural and phylogenetic in character. The classification based on test construction was, however, flawed and Kozur and Mostler (1983) point out that in the SEM cortical shells appeared to consist of pore frames with nodes and in many cases the shells were detached or



1 *Saturnalium* Haeckel

2 *Saturnalis* Haeckel

3 *Acanthocircus* (Squinabol)

4 *Palaeosaturnalis* Donofrio & Mostler

5 *Austrisaturnalis* Kozur & Mostler

6 *Spongosaturnaloides* Kozur and Mostler

7 *Pseudosaturnalis* Kozur & Mostler

8 *Palasaturnalis* Kozur & Mostler

Textfig. A.1.1 Saturnalid genera (after Donofrio and Mostler, 1978)

FAMILY SUBSUPERFAMILY	**SUBFAMILY**	**GENUS**
1) Presence of spongy cortical shell arranged in concentric layers.	1) Presence of polar spines.	1) Structure of ring (single, double, multiple).
2) Presence of latticed medullary shells.	2) Presence of polar and auxiliary spines.	2) Disposition and number of polar spines.
3) Presence of ring(s) connected to cortical shell by polar spines.	3) Size and disposition of spongy cortical shell.	3) Presence or absence of auxiliary spines.

Textfig. A.1.2 Classification of saturnalids at family, subfamily and generic level (after Pessagno *et al.*, 1979) dissolved from the ring.

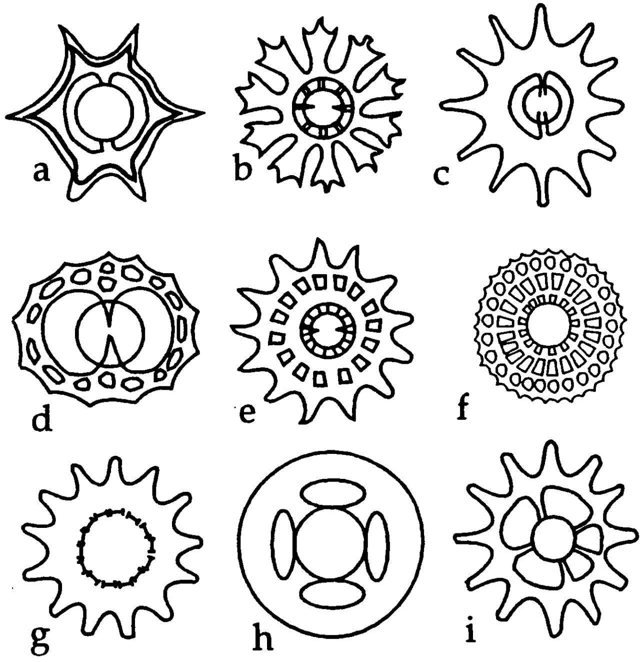
De Wever (1979 p. 79) conservatively retained the saturnalins as a subfamily of the actinomids, however, he conceded that the group may well be elevated to family status at a later date. The majority of his specimens had a flat ring which is generally characteristic of the Triassic forms, whereas, the Jurassic and Cretaceous forms have bladed rings.

Kozur (1979) described *Pessagnosaturnalis* as a new genus of the Family Saturnalidae. This genus is synonymous with *Spongosaturnalis* Kozur and Mostler, 1972 with the type species being *Spongosaturnalis heisseli* Kozur and Mostler, 1972 and is therefore invalid, although, this "new" genus (*Pessagnosaturnalis*) contains saturnalids with auxilliary spines on the inner margin of the ring.

De Wever (1981) published a study which included examples of the Parasaturnalidae from the Lower Jurassic of Turkey and followed the emendments made by Pessagno *et al.* (1979). Several new species were figured together with a diagram showing the variation within the Parasaturnalidae Kozur and Mostler, 1972 emend. Pessagno, 1979 (Textfig. A.1.3).

Dumitrica *et al.* (1980, p. 4, Pl. 10) described the Family Oertlispongidae. This family is thought to be the ancestral stock for the Mesozoic forms and ranges from the Lower Palaeozoic to the Upper Triassic. The family was based on five new genera, with early forms having up to ten shells and external spines which evolved and later fused to form the sagittal ring.

In 1981, Kozur and Mostler emended the Subfamily Saturnalinae Deflandre, 1953 and introduced the new Subfamily Palaeosaturnalinae, which had two new genera assigned: *Mesosaturnalis* (with its type species *Palaeosaturnalis levis* Donofrio and Mostler, 1978), and *Praemesosaturnalis* (with *Spongosaturnalis bifidus* Kozur and Mostler, 1972 as the type species). They also emended the following genera: *Spongosaturnaloides, Palaeosaturnalis, Pessagnosaturnalis.* Kozur and Mostler also challenged the validity of the emendments made by Pessagno *et al.* (1979), suggesting that the changes made the group even more artificial than before and resulted in members of several distinct families and even suborders beingplaced in the same families and subfamilies. They disagreed with Pessagno *et al.* (1979) over the separation of radiolarians with spongy and latticed shells at a high taxonomic level.



a, b, c : Forms with polar plane and single ring.

d, e, f : Forms with a polar plane and a double (d, e) or triple (f) ring.

g, h, i : Forms without polar plane.

a: *Acanthocircus hexaspina*
b: *Pseudoheliodiscus kahleri*
c: *Acanthocircus triassicus*
d: *Japonisaturnalis japonicus*
e: *Heliosaturnalis magnus*
f: *Heliosaturnalis multiperforatus*
g: *Pseudoheliodiscus radiosus*
h: *Austrisaturnalis quadriradiatus*
i: *Spongosaturnaloides quinquespinosa*

Textfig. A.1.3 Morphological variations within the Parasaturnalidae (after De Wever, 1984, p. 140)

Kishida and Sugano (1982) produced a zonation scheme from Japanese samples in which the youngest Triassic radiolaria were placed in the *Spongosaturnalis multidentatus* Zone which is typified by species of the genus *Spongosaturnalis* Campbell and Clark, 1944 (Blome, 1984 *Spongosaturnalis* = *Acanthocircus* Squinabol 1903) and *Palaeosaturnalis* Donofrio and Mostler, 1978 (Blome, 1984 some forms = *Pseudoheliodicus* Kozur and Mostler, 1972).

A new suborder, the Entactinaria, was established by Kozur and Mostler (1982). This group has an internal spicular system as found in Nassellarians and single, double or multiple shells as in Spumellarians. The Entactinaria were the most abundant group during the Palaeozoic, common in the Upper Triassic, but rarely present from the Rhaetian to Recent. The Parasaturnalidae are classified in the Entactinaria.

Yao (1982) reported *Palaeosaturnalis, Acanthocircus* and *Pseudoheliodiscus* within the *Triassocampe nova* assemblage (Triassic, Carnian-Norian) of Japan.

Kozur and Mostler (1983) emended all the then-known genera of Mesozoic saturnalids, except the Saturnalidae, and a total of two new families, three new subfamilies, six new genera and 12 new species were established. They based their classification on outline, cross-section, width and outer sculpture of the ring, and shape and form of attachment of the shells to the ring. The saturnalids within the Suborder Entactinaria Kozur and Mostler, 1982 are placed there because they have an internal spicular system.

Blome (1984) produced an Upper Triassic radiolarian zonation scheme for western North America. Members of the saturnalid group were used to define zones, such as the top of the Capnodoce Zone (middle Norian) where the apparent final appearances of *Acanthocircus dotti* Blome, 1984 and *A. harrisonensis* Blome, 1984 occur. The first occurrence of *Pseudoheliodiscus finchi* Pessagno, 1979 marks the base of the Betraccium Zone (middle Norian).

A revision of all Mesozoic saturnalids based on an hierarchy of characters was carried out by De Wever (1984). The characters in order of significance were:

1) presence or absence of polar spine
2) whether spines are polar or peripolar
3) presence or absence of auxilliary rays
4) ring single or multiple

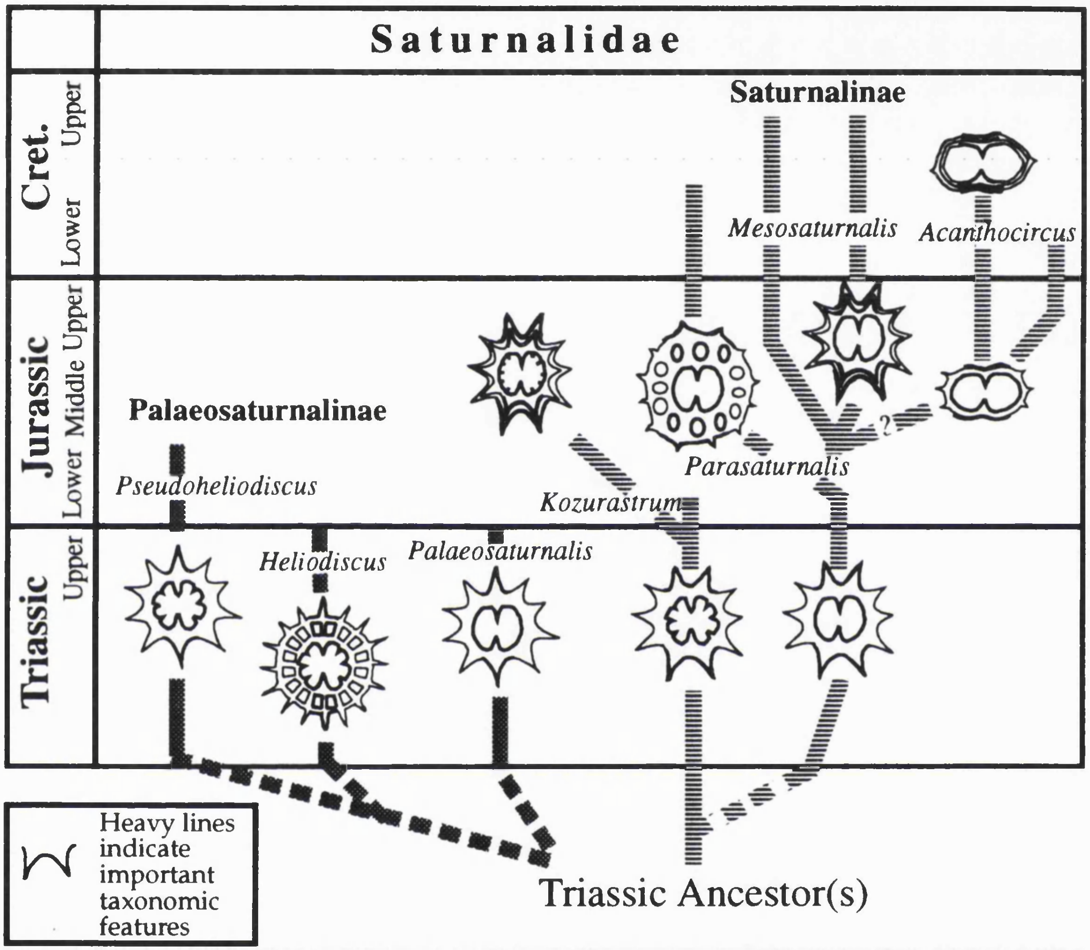
5) ring ribbed or not.

De Wever grouped all saturnalids with two polar rays into the Saturnalidae, containing the subfamilies Saturnalinae and Palaeosaturnalinae. The Saturnalinae comprising *Palaeosaturnalis, Heliosaturnalis* and *Pseudoheliodiscus* and the Palaeosaturnalinae consisting of *Saturnalis, Acanthocircus, Mesosaturnalis, Kozurastrum* and *Parasaturnalis.* A phylogenetic scheme for Mesozoic saturnalids was proposed (Textfig. A.1.4).

Yoshida (1986) introduced two (?)middle Norian subzones based on saturnalids. Both subzones occur between the *Capnodoce* Zone below and the *Betraccium deweveri* Zone above. The *Acanthocircus* Subzone is characterised by the presence of the *Acanthocircus* spp. and occurs above the *Capnodoce* Zone, and the *Pseudoheliodiscus* Subzone characterised by the presence of *Pseudoheliodiscus* spp. rests on top of the *Acanthocircus* Subzone. Specimens recovered (Yoshida 1986, Pl. 15, 16, 17) resemble those illustrated by Kozur and Mostler (1972), Yao (1982), Blome (1984), and several forms from the present study.

Kozur and Mostler (1990) established two new families, seven new genera and 63 new species from the Hettangian of Bavaria. General faunal turn-over is discussed together with specific examples of saturnalid evolution. Change at a species level is most common from the Rhaetian to Hettangian in the saturnalids. Elongate and quadratic forms appeared in the Norian and Rhaetian and only became common in the Lower Jurassic. Many species of *Pseudoheliodiscus* Kozur and Mostler, 1983, *Liassosaturnalis* Kozur and Mostler, 1990 and *Pseudacanthocircus* Kozur and Mostler, 1990 appeared in the Hettangian. The authors agree with De Wever (1981, 1984) that the position of the polar/peripolar spines is important, however, the significance of this feature above for supra-specific taxonomy is disputed. Kozur and Mostler report that from the Norian to Recent the forms have either polar or peripolar spines within a group. In the Pseudoacanthocircidae Kozur and Mostler, 1990 only taxa with peripolar spines are known (Kozur and Mostler, 1990). The presence or absence of auxiliary spines is recognised as a method of distinguishing various genera, however, the "form pairs" of Kozur and Mostler, 1990 have auxiliary spines present in some groups and absent in others within one 'form pair'.

The main problem with the taxonomy of saturnalids is the independent and iterative development of the same features in different lines of development, which occur at



Textfig. A.1.4 Phylogeny of Mesozoic saturnalids (after De Wever, 1984) different times (Kozur and Mostler, 1990). Various evolutionary changes were listed by Kozur and Mostler (1990):

1) development of a second latticed medullary shell around the microsphere, leading in some cases to the development of a latticed cortical shell;
2) development of a narrow differentiated ring (with ridges);
3) development of a narrow, transversely oval to rectangular ring (long axis perpendicular to polar/peripolar spines);
4) reduction in the number of auxiliary spines;
5) appearance and disappearance of auxiliary spines;
6) development of double rings.

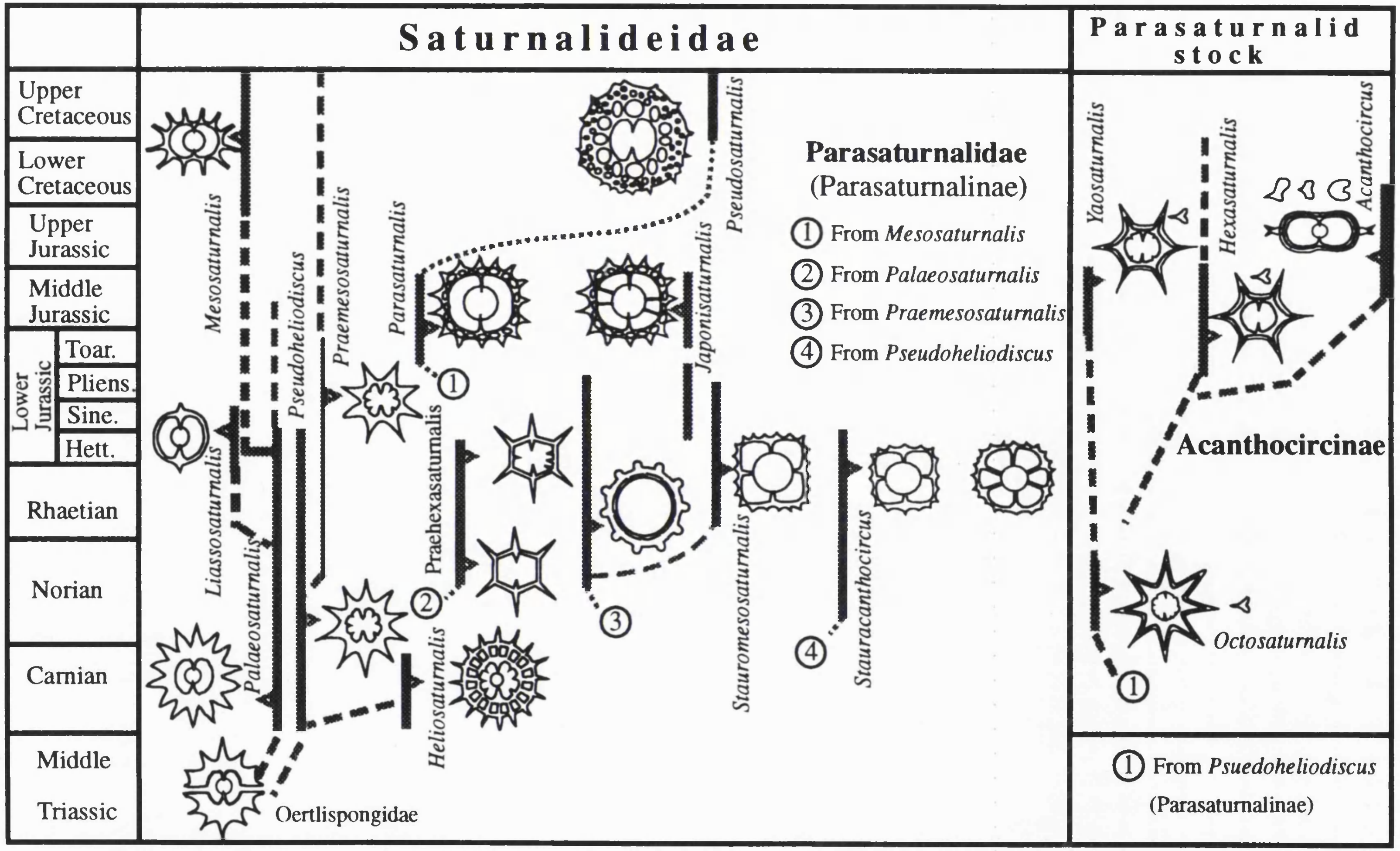
A.1.1.4 Discussion

The taxonomy of the saturnalids, as with several groups of radiolarians, is complex, poorly understood and still in a state of flux. Wherever possible in this study, a suprageneric classification is used following the classification of De Wever (1984). Kozur and Mostler produced a phylogenetic diagram (Textfig. A.1.5) which, at a generic level, is similar to that of De Wever (1984) although, at a higher level is markedly different. The 1990 publication by Kozur and Mostler reported that certain features used to split groups (in De Wever, 1984) are, through time, not applicable (e.g. polar/peripolar spines) i.e. that homeomorphy takes place. The taxonomic study of the saturnalids by Kozur and Mostler (1990) is partly used in this study, although only for the genus *Stauracanthocircus*.

A.1.2.0 Hagiastridae and Patulibracchiidae

A.1.2.1 Introduction

The Hagiastridae was introduced by Riedel (1971) and the Patulibracchiidae defined by Pessagno (1971). Both families may be externally similar in appearance and it is this similarity which has led to confusion, as well as the use of different morphological features by different workers to classify genera. For the pupose of this study the classification of Baumgartner (1980) was used to define members of the Hagiastridae and Patulibrachiidae and not the morphological features (especially of ray tip morphology) used, for example, by Yeh (1987).



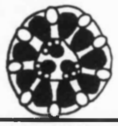
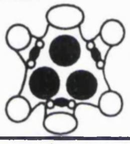
Textfig. A.1.5 Phylogeny of Mesozoic saturnalids (after Kozur and Mostler, 1990)

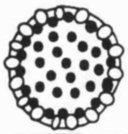
A.1.2.2 Classification used herein

Riedel (1971) described the rays of members of the Hagiastrinae as "Several strong, longitudinal elements from which arise branches which form a regular spongy meshwork." Pessagno (1971) defined the structure of the rays as "Meshwork arranged in parallel to subparallel layers axially. Individual layers comprise of pore frames arranged linearly to sublinearly." The group was raised to family level and placed in the Spongodiscacea (by Pessagno, 1971) and into the Spongodiscidae Haeckel emend. Riedel (by Riedel, 1971). Pessagno (1971, 1975, 1977, etc.) described species of the Hagiastridae using only the external structure. Kozur and Mostler (1978) did not believe that the external pore arrangement and internal structure of these groups were of supraspecific importance.

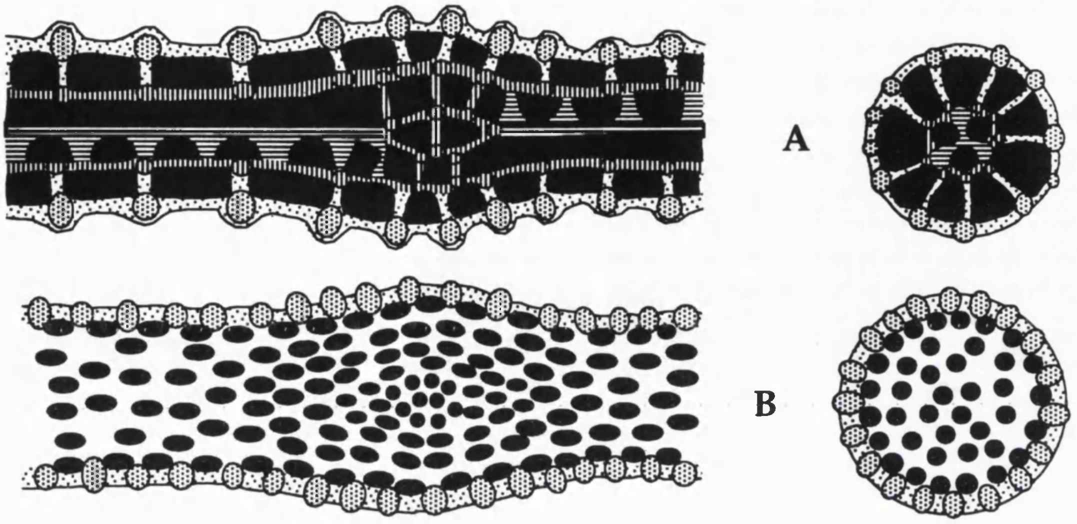
Baumgartner (1980) completely revised the classification of these forms and so attempted to reflect the relationship between the internal structure and external arrangement of pores. This classification comprehensively changed the generic content of the Hagiastridae and was based on the internal canal variations observed within the family, whereas the Patulibracchiidae encompassed those forms lacking discrete inner shells (Textfig. A.1.6). De Wever (1982) believed that the bracchiopyle was significant taxonomically (Textfig. A.1.8), however, this feature was later found to be transient in its appearance in individual specimens.

The Hagiastridae are characterised by continuous canals in the rays and concentric shells in the central area (Baumgartner, 1980), together with a radially symmetric arrangement of longitudinal internal structures (Textfig. A.1.7). The Patulibracchiidae as emended by Baumgartner (1980) has a definition similar to the original definition given in Pessagno (1971). The inner part of the rays in this family consists of uniform meshwork arranged in layers parallel to the equatorial plane of the shell (Baumgartner, 1980) (Textfig A.1.7). Internal structures are reflected externally by the reduced linearity of the pores, although some longitudinal structures are still present and form the basis for taxonomic division from other groups (such as the Spongobracchiidae Haeckel *emend.* Kozur and Mostler, 1978).

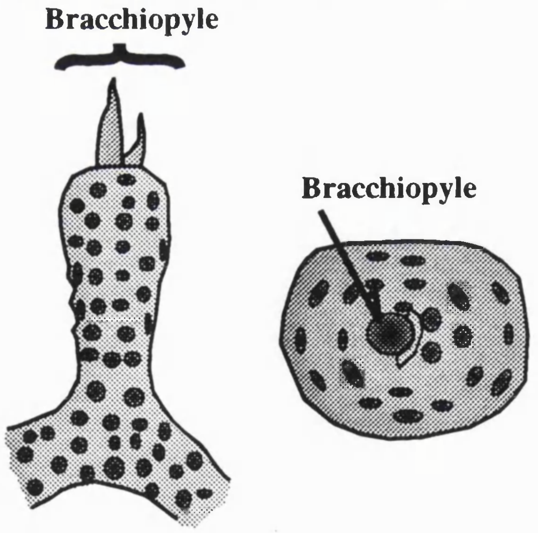
Family HAGIASTRIDAE Riedel **emend.** Baumgartner, 1980: Cortical and medullary shell, canals.			
Subfamilies: Nature of ray-cross-section	Genera: - Number of rays:		
	2	3	4
Hagiastrinae 	*Didactylum* Baumgartner	*Homeoparonaella* Baumgartner	*Hagiastrum* Haeckel
Higumastrinae 	not known	indeterminate	*Higumistra* Baumgartner
	not known	not known	*Pseudocrucella* Baumgartner
Tetrabinae 	*Ditrabs* Baumgartner	*Tritrabs* Baumgartner	*Tetratrabs* Baumgartner
Tetraditryminae 	not known	not known	*Tetraditryma* Baumgartner

Subfamilies: Nature of ray-cross-section	2	3	4
Patulibracchiinae 	*Amphibrachium* Muller	*Paronaella* Pessagno *Patulibracchium* Pessagno	*Crucella* Pessagno
Angulobracchiinae 	not known	*Angulobracchia* Baumgartner *Halesium* Pessagno	indeterminate

Textfig. A.1.6 Internal structure of Hagiastridae and Patulibracchiidae (after Baumgartner, 1980).



Textfig. A.1.7 Internal structure of the Hagiastridae (A) and the Patulibracchiidae (B) (after Baumgartner, 1980)



Textfig. A.1.8 Diagram illustrating the bracchiopyle (after De Wever, 1982)

A.1.3.0 Livarellidae

The Livarellidae in this study are interpreted *sensu* Kozur and Mostler (1981) and not as the emended version of Yeh (1992). Carter (1993) also uses the Family Livarellidae *sensu* Kozur and Mostler (1981) in which the test is hollow and believed to be of uncertain origin, unlike the definition of Yeh (1992) in which these taxa are believed to be dicyrtid nassellarians. The internal structure of the Livarellidae was illustrated (in Yeh, 1992), however, these illustrations are not conclusive and so are given no ordinal affiliation.

A.1.4.0 Systematic Palaeontology of Late Triassic Radiolarians

A.1.4.1 Introduction

The taxonomy in this study follows the systematic classification of Riedel (1967, 1971). This has subsequently been modified by various workers such as: De Wever (1979, 1981a, 1981b, 1982, 1984), Dumitrica (1978), Kozur and Mostler (1972, 1979, 1981, 1983, 1990), Nakaseko and Nishimura (1979), Carter (1989, 1990, 1993), Yeh (1987, 1990, 1992), Pessagno *et al.* (1979, 1980), Blome (1983, 1984, 1988), Yoshida (1986). Taxonomic confusion is still being caused by the existence of a number of definitions of certain groups such as the saturnalids. Where such groups are concerned, an explanation of why a particular definition is used in preference to another is provided either in the text or in Chapter 5 (Stratigraphic and taxonomic problems). Carter (*pers. comm.*, 1990, 1993) has provided the biostratigraphic framework for this study; with a direct personal comparison made by the author between the faunas from the Queen Charlotte Islands and those of this study, assemblages from North America, Europe, the Philippines, Japan, China and New Zealand are also compared to those reported herein. Complex groups such as the saturnalids, Hagiastridae, Patulibracchiidae and others are dealt with in Chapter 5 which is concerned with general problematica.

The taxonomy of the Late Triassic age Radiolarians described herein are placed in the appendices because they form the largest part of this study. This chapter is also separated from the taxonomic description of the Early Jurassic age taxa, which are less diverse, less well-preserved (in calcite) and are stratigraphically separated.Some conservative taxa are present in the both Late Triassic and Early Jurassic age sediments. At generic level *Canoptum, Orbiculiforma, Pantanellium, Paronaella* and *Crucella* occur across the Triassic-Jurassic boundary. The most striking difference in the assemblages occurring in the Late Triassic is that, compared to younger assemblages, there is a much greater ratio of Spumellarians to Nassellarians.

A.1.4.2 Notes on Systematics

1) *= designated type species
2) Noil=Indonesian for river
3) specimens marked "lost" were broken during preparation for the SEM
4) Catalogue Numbers for each specimen refer to photographic film and frame numbers (e.g. Film 3020/ frame number 15). Illustrations of the same specimen for close-ups or at different angles bear the same catalogue number, with a different figure number.
5) Taxa from this study which show affinity with (sp. aff.) a previously described species have the original description of the species provided with the differences of the taxa from this study explained under *Remarks:*.
6) Specimens marked "not illustrated" are given a catalogue number which represents their sample number.
7) Within this systematic section, "*Range:* " refers to the range given by the author who designated the species originally, or when a more recently published range is known . The terms 'upper' or 'late' and their uses are explained in Chapter 6 which is concerned with general problems encountered in this study. "*Range:*" generally refers to information gained from the literature, but where a new species is described "*Range:*" is the range of the species believed to apply within the sediments studied herein.
8) Measurements (using the Y and Z directions for the description of pore frames) follow the scheme of Pessagno and Blome, 1980.
9) Species which are biostratigraphically significant to this study are marked in **bold** on the plate explanations

Phylum **PROTOZOA**
Subclass **RADIOLARIA** Müller, 1858.
Order **POLYCYSTINA** Ehrenberg, 1838, **emend.** Riedel, 1967.
Suborder **SPUMELLARIA** Ehrenberg, 1875
Family **PANTANELLIDAE** Pessagno, 1977, **emend.** Pessagno and Blome, 1980.
Subfamily **CAPNODOCINAE** Pessagno, 1979, **emend.** Blome, 1983.

Description: (Blome, 1983 p. 23 emended the diagnosis of Pessagno *et al.,* 1979 as follows): Test as for family. Test with hollow, tubular primary spines and radial beams, two to four in number. Proximal and medial portions of each primary spine smooth, circular in axial section; distal portions triradiate in axial section with three prominent pores, each pore situated in grooves between internal partitions of the triradiate structure. Primary spines and radial beams divided by tripartite internal partitions. Ridges of external triradiate structure continuous with internal tripartite partitions. Secondary radial beams solid, connecting cortical shell and single medullary shell to nodal points.

Range: Upper Triassic (upper Carnian-upper middle Norian).

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Capnodoce De Wever, 1979 *Loffa* Pessagno, 1979 *Renzium* Blome, 1983.

Remarks: The Capnodocinae differs from Pantanellinae Pessagno and Blome, 1980 by possessing hollow, tubular rather than solid, bladed primary spines and radial beams (Blome 1983).The terminology for describing thickness of bars of pore frames among the Capnodocinae is presented in Pessagno and Blome (1980), and may be summarized as: Y = thickness of bar as measured in a plane tangential to test surface. Z = thickness of bar measured in a plane at right angles to test surface.

Genus *CAPNODOCE* De Wever, 1979, **emend**. Blome, 1983.

Type species: Capnodoce anapetes De Wever, 1979, emend. Blome, 1983

Description: (of Blome, 1983 p. 23) Cortical shell as with family and subfamily. Cortical shell with three equidistant or non-equidiatant, hollow, tubular primary spines; primary spines symmetrically or asymmetrically arranged, usually occurring in the same plane.

Range: Upper Triassic (upper? Carnian-middle Norian).

Occurrence (literature): Baja California, California, Oregon, Queen Charlotte Islands, Washington, British Columbia, Sicily, Turkey, Philippines, Japan.
Occurrence (this study): W. Timor, Indonesia.

Remarks: The emended definition by Blome (1983 p. 23) is used in this study.

Capnodoce anapetes De Wever, 1979.
Pl. 1, figs. 1, 11.
Cat. Nos. 3073/8, 3073/27.

*1979 *Capnodoce anapetes* De Wever in De Wever *et al.*, p. 82, Pl. 2, figs. 5-7.
1980 *Capnodoce anapetes* De Wever; Baumgartner, p. 298, Pl. 1, figs. 5, 6 (reworked material).
1983 *Capnodoce* sp. aff. *C. anapetes* De Wever; Blome, p.23, Pl. 8, figs. 3, 10, 11.
1984 *Capnodoce* sp. aff. *C. anapetes* De Wever; Blome, p.32, Pl. 4, fig 18.
1990 *Capnodoce* sp. aff. *C. anapetes* De Wever; Yeh, p. 13, Pl. 14, fig. 3.
1991 *Capnodoce* sp. aff. *C. anapetes* De Wever; Bragin, p. 83, Pl. 6, fig. 10.

Original description: (of De Wever, 1979 p. 82) Sphere with three prominent tubes. Cortical shell has large pores, approximately ten on the circumference, and a thick wall. Due to poor preservation, the characters of the medullary shell are not well known. The three tubes, disposed in one plane and of equal length, increase in width distally and are somewhat flared terminally. Width increases rapidly proximally, then only slightly and again rapidly distally. Their outward opening shows a hole divided into three parts by three blades which terminate in a small point beyond the tube itself. These blades extend throughout the length of the tube.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	92	94	87
Lengthof arms	112	115	110
Width of arms	40	44	38

Material: 24 specimens

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon, Greece, Sicily, Turkey, Philippines.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 233-234, 223).

Remarks: Blome (1983) distinguishes *C. anapetes* De Wever, 1979 from *C. anapetes* De Wever, 1979 emend. Blome, 1983 by pointing out that his own specimens have a more subtriangular cortical shell and possess primary spines which are slighty tapering proximally. Generally, variations are evident in changes in the shape of the cortical shell and some forms (Yeh, 1990) have subcylindrical distal portions of the primary spines.

Capnodoce sp. aff. ***C. copiosa*** Blome, 1983
Pl. 1, fig. 10.
Cat. No. 3057/3.

aff. *1983 *Capnodoce copiosa* Blome in Blome, p. 25, Pl. 6, figs.2, 12, 14, 16.
aff. 1984 *Capnodoce copiosa* Blome; Blome, p. 34, Pl. 4, fig. 5.

Original description: (of Blome, 1983 p. 25) Cortical shell moderate in size, circular in outline, with rounded sides. Meshwork consists of large, pentagonal and hexagonal (mainly hexagonal) pore frames with well-developed nodes at the pore frame vertices; nodes high in relief. Bars of pore frames thin in Y direction, thick in the Z direction. Six pore frames visible on top and bottom surfaces along an axis in line with primary spines. Primary spines symmetrically arranged, moderate in length, straight, circular in axial section. Primary spines relatively narrow, thinner medially, expanding both proximally and distally. Distal ends triradiate in axial section, with relatively wide pores.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	114	118	98
Length of arms	104	109	91
Width of arms	40	45	36

Material: 31 specimens

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, W.Timor, Indonesia (Sample 232, 246, 223).

Remarks: Capnodoce sp. aff. *C. copiosa* differs from *C. copiosa* Blome, 1983 by having poorly preserved pore frames and slightly wider primary spines. Blome (1983) also distinguishes *C. baldiensis* Blome, 1983 and *C. miniscula* Blome, 1983 from *C. copiosa* by primary spines which are thinner medially and wider both proximally and distally. This species also differs from *C. antiqua* Blome, 1983 by having narrower, less massive primary spines.

Capnodoce fragilis Blome, 1983
Pl. 1, figs. 2, 3, Pl. 2, fig. 2.
Cat. Nos. 3020/15, 3054/5, 3020/10.

*1983 *Capnodoce fragilis* Blome in Blome, p. 26, Pl. 6, figs. 4, 8, 10; Pl. 11, fig. 5.
1984 *Capnodoce fragilis* Blome; Blome, p. 34, Pl. 4, fig. 11.
1986 *Capnodoce fragilis* Blome; Yoshida, p. 8, Pl. 10, fig. 6.
1989 *Capnodoce fragilis* Blome; Carter, p. 197, Pl. 1, fig. 1, 6.

Original description: (of Blome, 1983 p. 26) Cortical shell small in size, subcircular in outline, with rounded sides. Meshwork consisting of large, pentagonal and hexagonal pore frames with large well-developed nodes at the pore frame vertices. Nodes moderately high in relief. Bars of pore frames thin in Y direction, thick in Z direction. Six pore frames visible on top and bottom surfaces along an axis in line with axis of primary spines. Primary spines symmetrical arranged, extremely long, curved, circular in axial section. Primary spines narrow, maintaining approximately the same diameter over most of length. Distal ends triradiate in axial section, with well-developed, relatively wide pores.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	104	106	97
Length of arms	255	261	239
Width of arms	42	44	37

Material: 13 specimens

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon, Queen Charlotte Islands British Columbia, Central Japan.
Occurrence (this study): Noil Meto, Soe, W. Timor (Sample 231, 223).

Remarks: Blome (1983) distinguishes *Capnodoce fragilis* from *C. sinuosa* Blome, 1983 by the presence of longer primary spines, from *C. sarisa* De Wever, 1979 by primary spines that maintain the same diameter over most of their length and from other species of *Capnodoce* by having thin, often curved primary spines which are extremely long. Variations within this species usually involve the length and curvature of the primary spines, specimens recovered during this study tended to have longer primary spines than those of Blome's (1983) or Yoshida's (1986) figured examples.

Capnodoce insueta Blome, 1983
Pl. 1, figs. 4, 5.
Cat. Nos. 3015/23, 3015/25.

*1983 *Capnodoce insueta* Blome in Blome, p. 28, Pl. 6, figs. 5, 6, 11, 19; Pl. 7, figs. 1, 7, 15; Pl. 11, fig. 6.
1984 *Capnodoce insueta* Blome; Blome, p. 34, Pl. 4, fig. 12.

Original description: (of Blome, 1983 p. 28) Cortical shell small in size, circular in outline, with rounded sides. Meshwork consisting of large pentagonal and hexagonal (predominantly hexagonal) pore frames with large, well-developed nodes at the pore frame vertices, nodes high in relief. Bars of pore frames relatively thick in Y direction, extremely thick in Z direction. Five pore frames visible on top and bottom surfaces along an axis in line with the primary spines. Primary spines symmetrically arranged, moderate in length, and straight. Proximal portions circular in axial section, medial and distal portions elliptical to subtriangular in axial section. Primary spines flattened on all sides, increasing in width distally; distal ends triradiate in axial section, with well-developed, wide pores.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	109	112	105
Length of arms	218	222	207
Width of arms	36	41	34

Material: 20 specimens

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 239, 223, 216-217-218, 99+101).

Remarks: The type figures of *Capnodoce insueta* Blome, 1983 differ from *C. insueta* (this study) by having slightly shorter primary spines and from other species of *Capnodoce* by having the medial and distal portions of the primary spines elliptical to subtriangular in axial section and by having sides of the cortical shell flattened.

Capnodoce kochi Blome, 1983
Pl. 1, fig. 6.
Cat. No. 3020/11.

*1983 *Capnodoce kochi* Blome in Blome, p. 28, Pl. 7, figs., 2, 8, 9, 16.
1984 *Capnodoce kochi* Blome; Blome, p. 34-35, Pl. 4, fig 13.
?1986 *Capnodoce* cf. *C. kochi* Blome; Yoshida, p. 8, Pl. 10, fig. 7.
1990 *Capnodoce kochi* Blome; Yeh, p. 14, Pl. 15, fig. 3.

Original description: (of Blome, 1983 p. 28) Cortical shell moderate in size, circular in outline, with rounded sides. Meshwork consisting of large, pentagonal and hexagonal (predominantly hexagonal) pore frames with large well-developed nodes at the pore frame vertices. Nodes moderately high in relief. Bars of pore frames relatively thin in Y direction, thick in Z direction. Five to six pore frames visible on top and bottom surfaces along an axis in line with axis of primary spines. Primary spines symmetrically arranged, moderate in length, straight, circular in axial section; primary spines of medium width, thicker medially, tapering proximally and distally. Distal ends triaradiate in axial section, with well-developed wide pores.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	101	106	98
Length of arms	164	176	154
Width of arms	34	39	32

Material: 21 specimens

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon, Central Japan, Philippines.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 239, 229, 223).

Remarks: Blome (1983) differentiates *Capnodoce kochi* from *C. miniscula* Blome, 1983 and *C. traversi* Pessagno, 1979 by primary spines in the former that are thicker medially and taper both proximally and distally. This species also differs from *C. venusta* Pessagno, 1979 by having narrower less inflated primary spines. Yoshida (1986 Pl. 10, fig. 7) figures a specimen with much heavier nodes at the pore frame vertices than the holotype of Blome (1983 p. 28).

Capnodoce sp. A
Pl. 1, fig. 7.
Cat. No. 3054/2.

Description: Cortical shell moderate in size, circular in outline with rounded sides. Meshwork consisting of large, pentagonal or hexagonal pore frames with well-developed nodes at the pore frame vertices. Primary spines not arranged symmetrically, but have two thinner spines closer together, both of which from distal to proximal end. The distal end of the more slender primary spines terminates with one or two spines. All primary spines are, throughout their length, circular in axial section. The larger primary spine is slightly longer than the other two, however, it is much wider in axial section and is medially thickened with thinner proximal and distal ends.

Dimensions (microns):	Average of 7 specimens	max.	min.
Diameter of cortical shell	118	122	113
Length of arms	228	239	217
Width of arms	47	53	42

Material: 7 specimens

Range: Upper Triassic (upper Carnian-Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Capnodoce sp. A differs from *C. insueta* Blome, 1983 by having unequally sized primary spines that are not symmetrically arranged around the cortical shell.

Capnodoce sp. B
Pl. 1, figs. 8, 9, Pl. 2, Figs. 1, 3.
Cat. Nos. 3020/14, 3020/13, 3020/12, 3020/9.

Description: Cortical shell circular in outline with occasional flattening around the area of attachment of the primary spines to the cortical shell. Meshwork consisting of large, well-developed, pentagonal and hexagonal (predominently hexagonal) pore frames, with large, high relief nodes situated at the pore frame vertices. Primary spines vary slightly in length from one specimen to another; proximally, primary spines circular in axial section, rapidly increase in diameter distally and become triradiate in axial section. Primary spines terminate with a strong, tapering spinal shaft.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	103	110	98
Length of arms	208	225	187
Width of arms	42	47	37

Material: 10 specimens
Range: Upper Triassic (upper Carnian-Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Capnodoce sp. B differs from *C. insueta* Blome, 1983 by having strong and rapid distal expansion of the primary spines and from *C. sinuosa* Blome, 1983 by having wider, straight primary spines.

Genus *JUSTIUM* Blome, 1983.

Type species: Justium novum Blome, 1983.

Original decription: (of Blome, 1993, p. 42, 44) Cortical shell spherical to subspherical with two solid, bladed primary spines and radial beams in combination with hollow, tubular primary spine and radial beam; primary spines nonsymmetrically arranged, situated within the same plane. Solid primary spines triradiate in axial section, with alternating ridges and grooves, two solid spines closer together, often considerably shorter than the third spine. Third primary spine hollow, smooth, circular to subcircular in axial section, with three prominent pores; each pore situated in grooves between ridges of triradiate structure. Meshwork of cortical shell consisting of large pentagonal and hexagonal pore frames with large nodes occurring at pore frame vertices. First medullary shell spherical.

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): North America, Japan.
Occurrence (this study): West Timor, Indonsia.

Remarks: Justium is related to *Gorgansium* and is tentatively placed in the Capnodocinae by Blome (1983), however, differs from the rest genera in the Pantanellinae by possessing one hollow tubular primay spine.

***Justium*?** sp. A
Pl. 12, figs. 8, 9, 10.
Cat. Nos. 3746/12, 3746/11, 3746/5.

Description: Cortical shell large spherical in outline; meshwork consisting of poorly preserved polygonal pore frames. Two primary spines triradiate in axial section, moderately long with ridges and grooves which exhibit torsion. Third primary spine short, hollow and tubular.

Dimensions (microns):	Average of 5 specimens	max.	min.
Diameter of cortical shell	83	89	75
Length of longest arm.	72	83	49
Width of arms (at base)	21	24	19

Material: 5 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: This specimen differs slightly from *Justium novum* by having thicker pore frames with nodes at the vertices, longer primary spines.

Genus *LOFFA* Pessagno, 1979.

Type species: Loffa mulleri Pessagno, 1979 in Pessagno *et al.,* 1979

Original description: (of Pessagno, 1979 p. 177) Cortical shell as with family and subfamily but subpyrimoidal and having four radially arranged primary spines and radial beams. Primary spines have internal tripartite partitions, continuous with radial beams, and originating from four corners of subpyrimoidal cortical shell. First medullary shell spherical. Meshwork consists of pentagonal or hexagonal pore frames with generally well-developed nodes at the pore frame vertices.

Range: Upper Triassic (Norian).

Occurrence (literature): California, Oregon, British Columbia.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Pessagno differentiates *Loffa* from *Capnodoce* De Wever, 1979 by the presence of a subpyrimoidal test (although this is not always the case as *Loffa lepida* Blome, 1983 has a spherical cortical shell) with four primary spines which do not occur in the same plane, as opposed to a spherical to subspherical test with three radially arranged primary spines, he also points out that *Capnodoce sarisa* De Wever (1979, Pl. 2, figs. 8-12.) is probably assignable to *Loffa.*

Loffa lepida Blome, 1983
Pl. 2, figs. 4, 5.
Cat. No. 3053/34.

*1983 *Loffa lepida* Blome in Blome, p. Pl. 9, figs. 6, 9, 10, 13, 18; Pl. 11, fig. 4.
1984 *Loffa lepida* Blome; Blome, p. 36, Pl. 4, fig. 20.

Original description: (of Blome, 1983 p. 38) Cortical shell moderate in size, subcircular in outline. Meshwork consisting large, pentagonal and hexagonal pore frames with large well-developed nodes at the pore frame vertices. Nodes high in relief. Bars of pore frames thick in both Y and Z directions. Primary spines long, straight, circular in axial section. Primary spines relatively narrow, of equal width, maintaining approximately the same diameter over the length of the spine; distal end triradiate in axial section, exhibiting relatively narrow pores.

Dimensions (microns):	Average of 5 specimens	max.	min.
Diameter of cortical shell	94	102	91
Length of arms	206	219	192
Width of arms	32	37	27

Material: 5 specimens

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Loffa lepida may be differentiated from *L. vesterensis* Blome, 1983 by having a spherical cortical shell, and by having longer, narrower primary spines. Blome distinguishes this species from *L. mulleri* Pessagno, 1979 by longer, narrower primary spines.

Loffa sp. A
Pl. 2, figs. 6, 10, 11.
Cat. Nos. 3020/8, 3053/33, 3073/9.

Description: Cortical shell moderate in size subcircular in outline. Meshwork consists of pentagonal and hexagonal pore frames. Pore frames moderately well-developed with nodes moderatly high in relief. Primary spines moderately long, straight, circular in axial section, increasing in diameter distally and triradiate in axial section distally. Terminal spinal pores moderate in size.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	99	106	96
Length of arms	164	187	149
Width of arms	40	49	37

Material: 8 specimens

Range: Upper Triassic (Carnian-Norian).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: *Loffa* sp. A differs from *Loffa* sp. B by having primary spines which increase in diameter distally.

Loffa sp. B
Pl. 2, fig. 7.
Cat. No. 3054/2.

Description: Cortical shell moderate in size and circular in outline. Meshwork consists of pentagonal and hexagonal (predominantly hexagonal), very well-developed pore frames with prominent nodes located at the pore frame vertices; bars moderately thin in the Y-direction and thick in the Z-direction. Nodes are moderately high in relief. Primary spines straight, moderate in length and are slightly narrower for the proximal 30µm. Primary spines are circular in axial section and are triradiate distally in axial section. Terminal pores moderate in size.

Dimensions (microns):	Average of 4 specimens	max.	min.
Diameter of cortical shell	110	118	107
Length of arms	142	148	139
Width of arms	40	46	38

Material: 4 specimens

Range: Upper Triassic (Carnian-Norian).

Occurrence (this study): Noil Meto, Soe W. Timor, Indonesia (Sample 232).

Remarks: Loffa sp. B differs from *L.* sp. A by having much shorter primary spines which increase in diameter distally.

Genus ***RENZIUM*** Blome, 1983.

Type species: Renzium webergorum Blome, 1983

Original description: (of Blome, 1983 p. 40) Test as with family and subfamily. Cortical shell spherical to subspherical in outline, with two smooth, hollow, tubular bipolar spines. Meshwork of cortical shell consisting of large, pentagonal and hexagonal pore frames with nodes at the pore frame vertices. Secondary radial beams solid. First medullary shell spherical; meshwork poorly preserved in type species.

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon, California, British Columbia, Alaska.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Renzium Blome, 1983 may be differentiated from *Capnodoce* De Wever, 1979 by having two polar rather than three radially arranged spines.

Renzium adversum Blome, 1983.
Pl. 2, fig. 9.
Cat. No. 3275/35

*1983 *Renzium adversum* Blome in Blome, p. 40, Pl. 10, figs. 1, 6, 7, 12.
1984 *Renzium adversum* Blome; Blome, p. 36, Pl. 5, fig. 2.

Original description: (of Blome 1983, p. 40) Test as with genus. Cortical shell small subcircular in outline; meshwork consisting of a mixture of large pentagonal and hexagonal (predominently pentagonal) pore frames with massive nodes at the pore frames vertices. Bars of pore frames relatively narrow in the Y direction; wide in the Z direction. Five pore frames visible on top and bottom sufaces along an axis in line with the polar spines. Primary spines quite long, thin tubular, maintaining approximately same diameter over much of the length, distal portion occassionally expanding, triradiate distal portion poorly preserved in type material.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	84	97	81
Length of arms	123	129	118
Width of arms	38	43	34

Material: 15 specimens

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 239, 223, 216-217-218).

Remarks: Renzium adversum differs from *R. webergorum* Blome, 1983 p. 40, by having long and slender bipolar spines and a smaller cortical shell.

Renzium sp. A
Pl. 2, fig. 8.
Cat. No. 3057/16

Description: Cortical shell small, spherical in outline. Meshwork consists of a mixture of pentagonal and hexagonal pore frames. Bars of pore frames very thick in the Y - direction and relatively thick in the Z - direction. Five pores visible on top and bottom surfaces along an axis in line with the primary spines. Primary spines moderate in length, wide in diameter, slightly thinner proximally, becoming wider, in the medial portion and maintaining diameter to the distal termination of the spine. Distal portion of primary spine triradiate in axial section with secondary terminal spurs, proximally circular in axial section.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	90	98	87
Length of arms	140	145	136
Width of arms	38	40	35

Material: 11 specimens

Range: Upper Triassic (upper Carnian-Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: ***Renzium*** sp. A differs from other species of this genus by having primary spines which increase in width distally.

Subfamily **PANTANELLINAE** Pessagno, 1977.

Type genus: Pantanellium Pessagno, 1977

Original description: (of Pessagno, 1977) Test with two to four solid, bladed, radially arranged primary spines. Bladed primary spines comprise of alternating ridges and grooves.

Range: Upper Triassic (upper middle Norian) to Lower Cretaceous.

Occurrence (literature): World-wide.
Occurrence (this study): W. Timor, Indonesia.

Included genera: Betraccium Pessagno, 1979, *Cantalum* Pessagno, 1979, *Gorgansium* Pessagno and Blome, 1980, *Pantanellium* Pessagno, 1977.

Remarks: The Pantanellinae differ from the Capnodocinae by having primary spines that are not hollow and tubular, but consist of ridges and grooves which often exhibit torsion.

Genus *BETRACCIUM* Pessagno, 1979.

Type species: Betraccium smithi Pessagno, 1979, in Pessagno *et al.,* 1979.

Original description: (of Pessagno *et al.,* 1979 p. 177-178) Cortical shell subspherical with coarse polygonal meshwork as with family and with three radially arranged primary spines and radial beams situated in the same plane. Primary spines bladed, solid, having alternating ridges and grooves. First medullary shell spherical, latticed.

Range: Upper Triassic (upper Norian and Rhaetian).

Occurrence (literature): Oregon, Queen Charlotte Islands British Columbia, Philippines, Central Japan.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Betraccium differs from *Capnodoce* De Wever, 1979 in possessing solid, bladed primary spines and radial beams.

Betraccium deweveri Pessagno and Blome, 1980
Pl. 15, fig. 6
Cat. No. 3100/7

* 1980 *Betraccium deweveri* Pessagno and Blome in Pessagno and Blome, p. 230-231, Pl.1, figs. 1, 2, 5-8, 13, 14.
1984 *Betraccium deweveri* Pessagno and Blome; Blome, p. 37-38, Pl. 5, figs. 6, 7, 13, 20.
1986 *Betraccium deweveri* Pessagno and Blome; Yoshida, Pl. 13, figs. 6-9.
1991 *Betraccium deweveri* Pessagno and Blome; Bragin, p. 84, Pl. 7 figs. 13, 14.

Original description: (of Pessagno and Blome, 1980 p. 230-231) Cortical shell spherical with large, predominantly hexagonal pore frames having well-developed nodes at pore frame vertices; nodes moderately high in relief. Bars of pore frames thick in Y direction; moderately thick in Z direction. Five pore frame visible on trop and bottom surfaces along an axis in line with that of a given primary spine. Primary spines relatively long, triradiate in axial section, comprising of three wide grooves alternating with three narrow ridges; grooves three to four times wider than ridges; ridges and grooves displaying strong torsion.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	95	99	87
Length of arms	115	121	108
Width of arms	37	40	34

Material: 10 specimens

Range: Upper Triassic (upper Norian).

Occurrence (literature): Baja California, Alaska, Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 220).

Remarks: Pessagno and Blome, 1980 distinguish *Betraccium deweveri* Pessagno and Blome, 1980 from *B. maclearni* Pessagno and Blome (1980) and *B. yakounense* Pessagno and Blome, 1980 by a more spherical cortical shell and primary spines which exhibit extreme torsion of the ridges and grooves. The range of this species is used to define a radiolarian zone for the Norian and Rhaetian (see Blome, 1984), however, Carter, 1993, only found this marker in the upper Norian and suggested that the *B. deweveri* Zone be restricted to the narrow age bracket. During this study only a few specimens of *B. deweveri* were recovered and are believed to be found in the upper Norian/Rhaetian.

Genus *CANTALUM* Pessagno, 1979.

Type species: Cantalum holdsworthi Pessagno, 1979 in Pessagno *et al.,* 1979.

Original description: (of Pessagno, 1979 p. 178) Cortical shell as with family and subfamily but subpyramidal in shape and having four radially arranged primary spines and radial beams; primary spines continuous with radial beams, originating from four corners of cortical shell; spines and radial beams with alternating ridges and grooves. First medullary shell spherical.

Range: Upper Triassic (Norian).

Occurrence (literature): Alaska, Baja California, British Columbia, Japan.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Cantalum differs from *Betraccium* Pessagno, 1979 by having a subpyramidal cortical shell and four radially arranged primary spines.

Cantalum holdsworthi Pessagno, 1979
Pl. 15, fig. 7.
Cat. No. 3073/23.

*1979 *Cantalum holdsworthi* Pessagno in Pessagno *et al.*, p. 178, Pl. 2, figs. 9, 10, 13.

Original description: (of Pessagno, 1979 *et al.*, p.178) Cortical shell with coarse tetragonal and pentagonal pore frames. Primary spines solid, triradiate in axial section, with three grooves alternating with three relatively wide ridges; ridges and grooves displaying slight torsion; grooves tending to widen distally.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of central test	111	119	102
Length of spines	122	128	120
Width of spines	25	27	22

Material: 13 specimens

Range: Upper Triassic (Norian as far as known).

Occurrence (literature): Alaska, Baja California, British Columbia, Japan.
Occurrence (this study): Noil Meto, Soe, W. Timor Indonesia (Sample 246, 220, 216-217-218).

Remarks: The figured specimen of *Cantalum holdsworthi* differs slightly from the type specimen of Pessango (1979) by having tapering primary spines, however, this could be as a result of poor preservation of the type form.

Cantalum sp. aff. ***C. globosum*** Blome, 1984.
Pl. 15, fig. 8.
Cat. No. 3100/2.

aff.*1984 *Cantalum globosum* Blome in Blome, p. 39-40, Pl. 6, figs. 2, 10, 11, 18.

Original description: (of Blome, 1984 p. 39-40) Test as for genus. Cortical shell large, ovate in outline, with large, pentagonal and hexagonal pore frames having well-developed nodes at pore frame vertices; nodes high in relief. Bar of pore frames thick in both Y and X directions. Primary spines long triradiate in axial section, longitudinally comprise fo three wide grooves alternating with three narrow ridge; grooves three to four times as wide as ridges; ridges and grooves displaying strong torsion.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of central test	205	214	198
Length of spines	185	189	182
Width of spines	48	51	45

Material: 12 specimens

Range: Upper Triassic (upper Norian-Rhaetian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: C. sp. aff. *C. globosum* differs from the *C. globosum* Blome, 1984 by not having a cortical shell with large pentagonal and hexagonal pore frame, however, this may be as a result of poor preservation.

Cantalum sp. aff. ***C. holdsworthi*** Pessagno, 1979
Pl. 15, figs. 1, 9.
Cat. Nos. 3074/27, 3073/18.

aff.*1979 *Cantalum holdsworthi* Pessagno, p. 178, Pl. 2, figs. 9, 10, 13.

Original description: (of Pessagno *et al.*, 1979, p.178) Cortical shell with coarse tetragonal and pentagonal pore frames. Primary spines solid, triradiate in axial section, with three grooves alternating with three relatively wide ridges;ridges and grooves displaying slight torsion; grooves tending to widen distally.

Dimensions (microns):	Average of 6 specimens	max.	min.
Diameter of central test	84	79	85
Length of arms	96	110	85
Width of arms	35	38	32

Material: 6 specimens

Range: Upper Triassic (Norian as far as known).

Occurrence (literature): Alaska, Baja California, British Columbia, Japan.
Occurrence (this study): Noil Meto, Soe, W. Timor Indonesia (Sample 246).

Remarks: Specimens of *Cantalum* sp. aff. *C. holdsworthi* differs slightly from the type specimen of Pessango, by having tapering primary spines, however, this could be as a result of poor preservation of the type form and the primary spines with grooves and ridges exhibit no torsion.

Genus ***GORGANSIUM*** Pessagno and Blome, 1980.

Type species: Gorgansium silviense Pessagno and Blome, 1980

Original description: (of Pessagno and Blome, 1980 p. 234) Cortical shell typically elliptical with three primary spines of unequal length usually occurring in same plane. Primary spines assymetrically arranged; two spines closer together, often considerably shorter than third spine. Cortical shell usually compressed in the plane of threee primary spines. First medullary shell small , spherical with fragile pores frames.

Range: Upper Triassic (lower Carnian) to Upper Jurassic (Tithonian).

Occurrence (literature): Oregon, California, Baja California, Alaska, British Columbia, New Zealand, Middle East, Japan, Philippines.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Gorgansium differs from *Betraccium* by having two shorter primary spines which are situated closer to each other than the longer third spine.

?***Gorgansium*** sp. A
Pl. 12, fig. 5.
Cat. No. 3746/3.

Description: Cortical shell elliptical in outline, elongate along axis AB; comprised of large pentagonal and hexagonal pore frames with nodes at vertices. Five to six pore frames visible along AB; five pore frames visible along CD. Bars of pore frames thick; thickness about equal along Y and Z. All three primary spines unequal in length, triradiate in axial section; comprise of three relatively wide grooves which alternating with three narrow ridges which gradually become narrower distally.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	71	78	68
Length of longest arm.	64	69	62
Width of arms (at base)	19	22	17

Material: 12 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, W. Timor, Indonesia (Sample 232, 231, 246).

Remarks : This species is rather similar to *G. vallieri* Pessagno and Blome, 1980 (p. 235, Pl. 9, figs. 10, 15), however, it has thicker pore frames and nodes at the pore frame vertices.

Gorgansium sp. B
Pl. 12, figs. 3, 4.
Cat. Nos. 3746/1, 3746/8.

Description: Cortical shell small, spherical; comprised of well-developed pore frames which are thick in the Y direction and thicker in the Z direction. No nodes are visible at the pore frames vertices, although this may be a factor of preservation. The three primary spines are all of different lengths, triradiate in axial section, becoming rapidly broader proximally with moderately thick ridges and wide grooves and all show a degree of torsion. The longest primary spine approximately twice the length of the others

Dimensions (microns):	Average of 5 specimens	max.	min.
Diameter of cortical shell	82	86	80
Length of longest arm.	122	135	112
Width of arms (at base)	37	44	33

Material: 5 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: This species differs from others described herein by having one very long primary spine with the other two being approximately half the length of the longest spine.

Gorgansium sp. C
Pl. 12, figs. 6, 7.
Cat. Nos. 3746/2, 3746/7.

Description: Cortical shell subspherical, elongate in the AB direction; comprised of well-developed pore frames, moderately thick in the Y direction and thicker in the Z direction, and with nodes developed at the pore frames vertices. The three primary spines appear to be of different lengths; these are moderately narrow proximally and taper slowly to the distal termination; primary spines triradiate in axial section with narrow ridges and moderately wide grooves; primary spines show torsion in the distal third of their length.

Dimensions (microns):	Average of 5 specimens	max.	min.
Diameter of cortical shell	78	83	75
Length of longest arm.	101	109	94
Width of arms (at base)	38	42	32

Material: 5 specimens

Range: Upper Triassic (lower middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W.Timor, Indonesia (Sample, 232, 205).

Remarks: This species is similar to Pessagno and Blome (1980) *Gorgansium* sp. F. (p. 236, Pl. 2 fig. 7) which has a range of Upper Triassic, lower (?) to upper middle Norian from the Rail Cabin Argillite of eastern Oregon.

Genus **PANTANELLIUM** Pessagno, 1977.

?*Sphaerostylus* Haeckel, 1881 (=nomen dubium). Type species, *Sphaerostylus zitteli* Rust, 1885, p. 291 (21), Pl. 29 (4), fig. 2. Inadvertent subsequent designation by Campbell, 1954. Non *Xiphostylus* Haeckel, 1881. Type species, *Xiphostylus attenuatus* Rust, 1885, p. 288 (18), Pl. 27, fig. 17. Inadvertent subsequent designation by Campbell, 1954.
Non *Xiphostylus* Haeckel, 1881. Type species, *Xiphosphaera gaea* Haeckel, 1887, p. 123, Pl. 14, fig. 5. Subsequent designation by Frizzel and Middour, 1951, p. 13; junior subsequent designation by Campbell, 1954, p. D73.
Non *Stylatractus* Haeckel, 1887. Type species. *Amphistylus neptunus* Haeckel, 1887, Pl. 17, fig. 6;=*Stylatractus neptunus* Haeckel, 1887, p. 328, Pl. 17, fig. 6. Subsequent designation by Campbell, 1954, p. D73.

Type species: Pantanellium riedeli Pessagno 1977.

Original description: (of Pessagno, 1977 p. 78, Pl. 6, fig. 6) Test divided into ellipsoidal to subspherical cortical shell and spherical first medullary shell, both with massive polygonal pore frames with nodes at vertices. Cortical shell with bipolar primary spines possessing well-developed alternating, longitudinally arranged arranged ridges and grooves. One spine often somewhat shorter than other. Primary spines interconnecting and occurring along same axes as primary beams which connect cortical shell to first medullary shell; diameter of two primary beams about half of primary spines. Secondary radial beams also connecting cortical shell; extending from nodal points of pore frame vertices of both cortical and first medullary shell.

Range: Upper Triassic (lower Carnian) to Lower Cretaceous (upper Aptian-Albian?)

Occurrence (literature): Worldwide; southern and northern Tethyan Provinces of the Tethyan Realm.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Pantanellium differs from *Protoxophotracus* Pessagno, 1973, by possessing bipolar spines with longitudinally arranged, alternating grooves and ridges.

Pantanellium sp. A
Pl. 12, fig. 1.
Cat. No. 3747/6.

Description: Cortical shell subspherical with relatively small poorly preserved pentagonal and hexagonal pore frames which have well-developed pores at the pore frame vertices. Polar spines triradiate in axial section proximally, becoming circular in axial section distally. Both spines long, tapering slowly with the spine terminations broad.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	76	79	75
Length of arm	95	108	92
Width of arms (at base)	35	37	34

Material: 13 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 220).

Remarks: Pantanellium sp. A differs from other species of *Pantanellium* described herein by having a relatively small, subspherical cortical shell and long polar spines.

Pantanellium sp. B
Pl. 12, fig. 2.
Cat. No. 3747/4.

Description: Cortical shell large, spherical with well-developed pores surrounded by pentagonal and hexagonal pore frames. Generally poorly preserved specimens still show development of nodes at pore frame vertices. Polar spines are short, robust and triradiate in axial section with one noticeably shorter than the other.

Dimensions (microns):	Average of 7 specimens	max.	min.
Diameter of cortical shell	65	72	60
Length of arm	56	67	42
Width of arms (at base)	25	27	23

Material: 7 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Family **CAPNUCHOSPHAERIDAE** De Wever, 1979 **emend**. Pessagno, 1979 **emend**. Blome, 1983.

Type genus: Capnuchosphaera De Wever, 1979

Description: (Emended definition of Blome, 1983 p. 13) Liosphaeracea with cortical shell comprised of two layers of polygonal pore frames. Cortical shell circular to tetragonal in outline, with three to four radially arranged, solid to hollow primary spines (tumidaspinae) and interconnecting primary and secondary radial beams, when present, connect cortical shell to first medullary shell. First medullary shell comprised of polygonal pore frames.

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Capnuchosphaera De Wever, 1979, *Icrioma* De Wever, 1979, *Sarla* Pessagno, 1979.

Remarks: (of Blome, 1983 p. 13) Capnuchosphaeridae differ from the Pantanellidae by possessing a double layered cortical shell. The genus *Capnuchosphaera* differs from *Capnodoce* in having an hollow central body and by having less well-developed pores.

Genus *CAPNUCHOSPHAERA* De Wever, 1979 **emend.** Pessagno, 1979 **emend.** Blome, 1983.

Type species: Capnuchosphaera triassica De Wever, 1979

Description: (Emended version of Blome, 1983 p. 13) Cortical shell circular to ovate in outline, with three radially arranged primary spines (tumidaspinae) in same plane. Surface of cortical shell convex. Outer layer of meshwork comprise of large, flat to raised, polygonal pore frames; some pore frames with variable sized, raised nodes at the pore frame vertices; pores circular to elliptical in outline; inner layer usually comprise of smaller, more uniformly sized polygonal pore frames, pores circular to subcircular in outline. Tumidaspinae symmetrically arranged; spinal tunnel hollow, smooth, circular to subcircular in axial section, base occasionally porate; spinal tumour sometimes prominent, swollen, triradiate in axial section with tumidapores in grooves between ridges of triradiate structure; spinal shaft solid, triradiate to circular in axial section. Spinal shafts with or without alternating ridges and grooves. Primary radial beams hollow, continuous, with spinal tunnels of tumidaspinae connecting cortical shell to first medullay shell.

Range: Upper Triassic (upper Carnian-middle Norian).

Occurrence (literature): Greece, Sicily, Turkey, Oregon, Baja California, California, Europe, Philippines, China, Japan.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Capnuchosphaera may be differentiated from *Sarla* Pessagno, 1979 by the presence of tumidaspinae. *Capnuchosphaera* differs from *Icrioma* De Wever, 1979 by possessing three as opposed to four tumidaspinae.

Capnuchosphaera colemani Blome, 1983.
Pl. 3, figs. 1, 2, 3, 12.
Cat. Nos. 3074/18, 3074/13, 3073/16, 3074/19.

*1983 *Capnuchosphaera colemani* Blome in Blome, Pl. 1, figs. 1, 2, 6, 7, 10, 15.

Original description: (of Blome, 1983 p. 15) Cortical shell moderate in size, ovate, with outer layer of variably sized triangular to pentagonal pore frames with subcircular pore;

inner layer of cortical shell consisting of polygonal pore frames equal to or smaller in size than those of outer layer, pores subcircular in outline. Tumidaspinae comprise of long spinal tunnels; proximal portion of spinal tunnels smooth; distal portion displaying indentations midway between tumidapores; spinal tunnels subcircular in axial section; spinal tumours prominent, with three large, well-developed tumidapores; spinal shafts circular in axial section; spinal shaft about half the length of a given tumidaspina.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	122	127	116
Length of arms	126	129	119

Material: 10 specimens

Range: Upper Triassic (upper Carnian? to lower -upper middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 232).

*Remarks:*This species may be differentiated from *C. triassica* De Wever, 1979 by having less massive tumidaspinae with spinal tumours exhibiting little or no tortion.

Capnuchosphaera constricta (Kozur and Mostler, 1981)
Pl. 7, fig. 1.
Cat. No. 3044/1

*1981 *Sulovella constricta* Kozur and Mostler in Kozur and Mostler, Pl. 64, figs 2a, 2b.
1990 *Capnuchosphaera crassa* Yeh, p. 8, Pl. 1, figs. 8, 11, 12, 13, 18, 19.

Original description: (Kozur and Mostler, 1981) Schale subsphärisch, spongios. Die drei Arme besitzen einen mit groben Langsporen versehenen Anfangsteil, der nach außen verjüngt ist. Übrige Teile der Arme glatt, mit jleinen unregelmäßigen Poren. In der Mitte befindet sich eine kraftige Einschnürung, die einen wenig aufgeblahten proximalen Teil von einem kräftig aufgeblähten distalen Teil trennt. Distal gehen die Arme in einen anfangs dreikantigen, distal runden kräftigenStachel über, der sich innerhalb der Arme fortsetzt.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of cortical shell	162	165	159
Total length of arms	107	220	218

Material: 34 specimens

Range: Upper Triassic (Carnian-Norian).

Occurrence (literature): Hungary, Austria, Slovakia, Italy, Philippines.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 223, 216-217-218).

Remarks: Capnuchosphaera constricta Kozur and Mostler, 1981, differs from *Capnuchosphaera lea* De Wever, 1979, *C. contracta* by having a swelling half way between the cortical shell and the tumour which is smaller than the main tumour and a raised crown of large pores around the base of each tumidaspinae. *C. constricta* differs from *C. contracta* Yeh, 1990 by having short thick tumidaspinae. *C. crassa* Yeh, 1990 is regarded as a junior synonym of *C. constricta.*

GENUS TUMIDASPHAERA

Tumidasphaera **kapanensis** n. sp.
Pl. 6, figs. 6, 8, 10, 11.
Cat. Nos. 3054/25 = Holotype fig. 6, Paratypes =3054/22, 3054/25, 3054/25 figs. 8, 10, 11.

Diagnosis: A species of Tumidasphaera distinguished by a mammilate cortical shell, pores on spinal tunnels and spinal shafts terminating in four rods.

Description: Cortical shell large, subcircular in outline. Meshwork comprises of variably sized pores on a slightly mammilate cortical shell surface; pores surrounded by polygonal pore frames with nodes at the vertices. Tumidaspinae consists of spinal tunnel with alternating longitudinal rows of large and fine pores separated by thick ridges and terminating in three distinct pores; distal end comprises of three radiating secondary spines with lamellae drawn out into a short spinal shaft, triradiate in axial section with three prominent circular pores between each of the radiating spines.

Dimensions (microns):	Average of 20 specimens	max	min.	Holotype
Diameter of cortical shell	153	158	152	152
Total length of arms	94	115	74	115
Width of arms	45	48	43	43
Length of proximal part of arm	42	53	36	45

Material: 45 specimens

Range: Upper Triassic (middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 231, 223).

Etymology: This species is named after the village of Kapan in West Timor, type area.

Type locality: River Meto sections, West Timor, Sample 223, 231, 223 (see Chapter 4, section logs).

Remarks: Capnuchosphaera kapanensis differs from other species of *Capnuchosphaera*, described herein, by having alternating rows of fine and coarse pores situated longitudinally along the spinal tumour, and by having pores between the radial terminal spinal shaft.

Tumidasphaera **metoensis** n. sp.
Pl. 6, figs. 1, 2, 3, 4, 5, 7, 9, Pl. 7, figs. 4, 5.
Cat. Nos. 3054/13 = Holotype Pl. 6, figs. 1, 9, Paratypes =3251/27, 3054/10, 3026/2, 3251/2, 3024/31, 3054/13, 3026/3, 3026/4 Pl. 6, figs. 2, 3, 4, 5, 7, Pl. 7, 4, 5.

Diagnosis: A species of Tumidasphaera distinguished by a mammilate cortical shell and a spinal shaft which has four rods.

Description: Cortical shell large subspherical with flattening around the base of each tumidaspina. Meshwork comprises of a mammilate surface of variably sized, subspherical pores surrounded by polygonal pore frames with nodes at the pore frame vertices. Tumidaspinae comprise of spinal tunnels with rows of pores (four in each row), separated by a ridge. The spinal tunnel terminates in three well-developed subcircular pores surrounded by a heavy rims; spinal tunnel comprises of half the length of any given tumidaspinae. The distal part comprises of a spinal shaft, triradiate in axial section, with three radial lamellae drawn out into spines and a short terminal, triradiate terminal spine.

Dimensions (microns):	Average of 20 specimens	max.	min.	Holotype
Diameter of cortical shell	195	214	187	207
Total length of arms	107	128	79	120
Width of arms	70	71	69	71
Length of proximal part of arm	65	78	54	60

Material: 67 specimens

Range: Upper Triassic (middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223, 231, 232).

Etymology: This species is named after the River Meto, in the type locality

Type locality: River Meto sections, West Timor, Sample 223, 231, 232 (see Chapter 4, section logs).

Remarks: Capnuchosphaera metoensis differs from other species of *Capnuchosphaera*, described herein, by having distinct wide spinal tunnels, and by having pores of equal size on the spinal tunnels.

Capnuchosphaera schenki Blome, 1983.
Pl. 4, figs. 1, 2.
Cat. Nos. 3073/15, 3073/7.

*1983 *Capnuchosphaera schenki* Blome in Blome, Pl. 1, figs. 4, 12, 14, 17.
1984 *Capnuchosphaera schenki* Blome; Blome, p. 28-29, Pl. 3, fig. 10.
1986 *Capnuchosphaera* cf. *C. schenki* Blome; Yoshida, Pl. 12, fig. 2.

Original description: (of Blome, 1983 p. 16) Cortical shell spherical, consisting of an outer layer of variably sized pentagonal and hexagonal pore frames with subcircular to circular pores; inner layer of cortical shell consisting of smaller, poorly preserved polygonal pore frames with subcircular pores. Tumidaspinae comprise of long, smooth spinal tunnels, circular in axial section; spinal tumours prominent, with three large, well-developed tumidapores; spinal shafts circular in axial section; spinal shaft about half length of a given tumidaspina.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	140	147	125
Length of arms	152	168	137

Material: 8 specimens

Range: Upper Triassic (upper Carnian-lower-middle Norian).

Occurrence (literature): Oregon, Central Japan.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Capnuchosphaera schenki differs from *C. colemani* Blome, 1983 and *C. smithorum* Blome, 1983 by having tumidaspinae with small tumours that are less massive in character, and by having longer spinal tunnels.

Capnuchosphaera timorensis n. sp.
Pl. 5, figs. 1, 2, 3, 4, 5, 6, 10, 11, 12, 13.
Cat. Nos. 3100/20 = Holotype figs. 1, 13, Paratypes =3100/26, 3074/12, 3100/30, 3056/29, 3100/24, 3056/29, 3100/26, 3100/20 figs. 2-6, 10-12.

Diagnosis: A species of *Capnuchosphaera* distinguished by pores frames which are high in relief and by extremely long spinal shafts.

Description: Cortical shell moderate in size, circular in outline. Meshwork comprises of variably sized pores surrounded by polygonal pore frames which are high in relief with nodes at the pore frame vertices. Tumidaspinae with very short spinal tunnels; wide and flaring lamellae at the spinal tumour and a very long spinal shaft; spinal tunnels and spinal shaft both circular in axial section.

Dimensions (microns):	Average of 15 specimens	max.	min.	Holotype
Diameter of cortical shell	175	190	159	160
Length of arms	268	342	197	215

Material: 19 specimens

Range: Upper Triassic (upper Carnian-upper middle Norian, as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 231, 246).

Etymology: This species is named after the island of Timor, site of type locality.

Type locality: River Meto sections, West Timor, Sample 223, 231, 232 (see Chapter 4, section logs).

Remarks: Capnuchosphaera timorensis n. sp. differs from *C. deweveri* Kozur and Mostler, 1979 by having much shorter spinal tunnels, more delicate lamellae at the spinal tumour and having longer spinal shafts compared to spinal tunnels. *C. timorensis* has spinal lamellae which exhibit torsion in a sinistral sense in a distal direction along the tumidaspinae.

Capnuchosphaera triassica De Wever, 1979.
Pl. 3, figs. 5, 6, 7, 8, 9, 11, 13.
Cat. Nos. 3251/9, 3073/11, 3074/30, 3074/16, 3074/26, 3074/26, 3073/12.

*1979 *Capnuchosphaera triassica* De Wever in De Wever *et al.,* p. 84, Pl. 4, figs. 3, 4, 5.
1990 *Capnuchosphaera triassica* De Wever; Yeh p. 9, Pl. 2 figs. 9, 10, 16, Pl 3, figs. 5, 10, 14, 15.

Original description: (of De Wever, 1979 p. 84) Spherical shape with three tubes of which the distal part is twisted and terminated in a point varying in length and sharpness. Sphere, thick-walled, is rough, without surface spines, and has rounded pores irregular in size and arrangement (approximately 10 in 100 m). the length of twisted part of the tube can vary but commonly represents 60% of overall length of the tube.

Dimensions (microns):	Average of 15 specimens	max.	min.
Diameter of cortical shell	121	123	119
Length of arms	156	190	124

Material: 22 specimens

Range: Upper Triassic (Carnian-Norian).

Occurrence (literature): Greece, Sicily, Turkey, Italy, Oregon.
Occurrence (this study): Noil Meto, West Timor Indonesia (Sample 232, 246, 223, 216-217-218).

Remarks: C. triassica has a wide variety of forms which has led to a certain amount of confusion in the published literature. Nakaseko and Nishimura (1979) illustrate (Pl. 7, figs. 4, 5, 6) specimens resembling *C. deweveri* Kozur and Mostler, 1979 (of Blome, 1983 Pl. 1, figs. 3, 8, 9, 16, 18). Lahm (1984, Pl. 14, figs. 8, 9) illustrated specimens of *C. triassica*, similar to some of the varieties of De Wever *et al.* (1979).

Capnuchosphaera sp. aff. ***C. constricta*** (Kozur and Mostler, 1981)
Pl. 7, figs. 6, 8.
Cat. No. 3057/9

aff.*1981 *Sulovella constricta* Kozur and Mostler in Kozur and Mostler, Pl. 64, figs 2a, 2b.
aff.1990 *Capnuchosphaera crassa* Yeh, p. 8, Pl. 1, figs. 8, 11, 12, 13, 18, 19.

Original description: See *Capnuchospheara constricta* above.

Dimensions (microns):	Average of 4 specimens	max.	min.
Diameter of cortical shell	170	175	168
Total length of arms	171	184	149

Material: 4 specimens

Range: Upper Triassic (Carnian-Norian, as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: C. sp. aff. *C. constricta* differs from the holotype of Kozur and Mostler, 1981 (with the specimens from Timor placed in the species) by having thicker more bulbous tumidaspinae with a notch and external rod just proximal to the main spinal tumour.

Capnuchosphaera sp. aff. ***C. smithorum*** Blome, 1983
Pl. 4, fig. 3.
Cat. No. 3100/13

aff.*1983 *Capnuchosphaera smithorum* Blome in Blome, Pl. 2, figs. 1, 6, 9, 15.
aff. 1984 *Capnuchosphaera smithorum* Blome; Blome, p. 29, Pl. 3, fig. 11.
aff. 1988 *Capnuchosphaera smithorum* Blome; Blome Pl. 33.1, fig. 10.

Original description: (of Blome, 1983 p. 17) Cortical shell large, spherical, consisting of outer layer of well-developed, variably sized polygonal (predominantly pentagonal and hexagonal) pore frames with subcircular to elliptical pores; inner layer of cortical shell consisting of smaller polygonal pore frames with subcircular pores. Tumidaspinae comprise of long, smooth spinal tunnels circular in axial section; spinal tumours prominent, with three large, well-developed tumidapores; small indentations midway between tumidapores at base of spinal tumour; spinal shafts circular in axial section; spinal shaft about half to two-thirds the length of a given tumidaspina.

Dimensions (microns):	Average of 6 specimens	max.	min.
Diameter of cortical shell	142	150	130
Length of arms	150	165	139

Material: 6 specimens

Range: Upper Triassic (upper Carnian?-lower- middle Norian).

Occurrence (literature): Oregon, Alaska.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Blome (1983) distinguishes *Capnuchosphaeara smithorum* Blome, 1983 from *C. colemani* Blome, 1983 by its larger, more spherical cortical shell. This species also differs from *C. theloides* De Wever, 1979 in having tumidaspinae with less massive and less triangular spinal tumours.

Capnuchosphaera sp. aff. ***C. theloides*** De Wever, 1979
Pl. 4, figs. 4, 5, 9, 10, 11, Pl. 5, figs. 7, 8, 9,
Cat. Nos. 3074/21, 3054/19, 3747/12, 3251/31, 3747/10.

aff. *1979 *Capnuchosphaera theloides* De Wever in De Wever *et al.*, Pl. 3, figs. 10, 11, 12, 13.
aff. 1986 *Capnuchosphaera theloides* De Wever; Yoshida, Pl. 12, fig. 4.
aff. 1990 *Capnuchosphaera theloides* De Wever; Yeh, Pl. 2, fig. 13, Pl. 3, fig. 12.
aff. 1991 *Capnuchosphaera theloides* De Wever; Bragin, p. 77-78, Pl. 5, figs. 41, 15.

Original description: (of De Wever, 1979 p. 85) Cortical shell small, subcircular in outline. Meshwork comprises of variably sized subcircular pores polygonal pore frames with variably sized nodes at the pore frame vertices. Tumidaspinae unequally spaced, smooth and terminating in a widely flaring spinal tumour. Spinal tunnels circular in axial section; spinal tumour triangular with triradiate lamellae terminating in a very short triradiate spinal shaft.

Dimensions (microns):	Average of 15 specimens	max.	min.
Diameter of cortical shell	128	141	107
Length of arms	120	138	85

Material: 34 specimens

Range: Upper Triassic (upper Carnian-upper middle Norian).

Occurrence (literature): Greece, Sicily, Turkey, Central Japan, Philippines.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 232, 223, 216-217-218).

Remarks: Specimens of the *C.* sp. aff. *C. theloides* illustrated herein differ from the holotype of De Wever (1979) by having tumidaspinae which terminate in a triradiate spinal shaft rather than a spine which is circular in axial section, others (Pl. 5, figs. 7, 8, 9) do have this spinal shaft. *Capnuchosphaera* sp. aff. *theloides* differs from *C. triassica* De Wever, 1979 in having three lamellae showing no torsion and lamellae which gently curve into the spinal shaft. Yoshida (1986) figures a poor specimen which appears to differ greatly from the holotype of De Wever, 1979. Yeh (1990, Pl. 3, fig. 12) has two figured specimens, one with straight tumoural lamellae (Pl. 2, fig. 13) and one with curved tumoural lamellae which is similar, to the specimen figured herein, with the exception of a relatively smaller spinal tumour.

Capnuchosphaera sp. A
Pl. 4, figs. 7, 8.
Cat. Nos. 3100/20, 3100/21.

Description: Cortical shell moderate in size, subcircular in outline with slight flattening around the bases of the tumidaspinae. Cortcal shell comprised of a mammilate surface. Meshwork comprised of small, subcircular pores surrounded by polygonal pore frames with nodes at the pore frame vertices. The nodes become enlarged at the pinnacle of mammilate tumour, which are arranged in a hexagonal pattern over the surface of the cortical shell. Tumidaspinae not symmetrically arranged around the cortical shell, smooth, relatively short, with an heavy, triangular spinal tumour. Three well-developed tumidapores are situated in the spinal tumour which is triangular in axial section. Spinal tunnel and spinal shaft circular in axial section. Spinal shaft accounts for half of the length of any given tumdaspina.

Dimensions (microns):	Average of 9 specimens	max.	min.
Diameter of cortical shell	194	197	189
Length of arms	183	175	143

Material: 9 specimens

Range: Upper Triassic (upper Carnian-middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 231, 229).

Remarks: Capnuchosphaera sp. A differs from *C. theloides* De Wever, 1979 by having a mammilate cortical shell and elongate spinal shafts which are circular in axial section.

Capnuchosphaera sp. B
Pl. 7, figs. 2, 9, 10.
Cat. No. 3100/22.

Description: Cortical shell large subcircular in outline, with flattened areas around the base of each primary spines. Meshwork consists of well-developed variably sized pore frames and circular to subcircular pores. Tumidaspinae long, smooth, with prominent swollen tumours at one third and at the distal end. Base of tumidaspinae consist of raised circular crown of pores; tumidaspinae circular in axial section, becoming triradiate in axial section at the distal end. Three ovate tumidapores visible at the base of the tumidaspina.

Dimensions (microns):	Average of 6 specimens	max.	min.
Diameter of cortical shell	196	203	194
Total length of arms	178	209	162

Material: 6 specimens

Range: Upper Triassic (Carnian-Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Capnuchosphaera sp. B differs from *Capnuchosphaera palawanensis* Yeh, 1990 and *C.* sp. aff. *C. crassa* by having two distinct swellings or tumours on the tumidaspinae. *C.* sp.B also differs from *C. contracta* by having a cortical shell more circular in outline and a more robust tumidaspinae. *C.* sp. B also differs from *C. lea* by having larger more developed tumours on the tumidaspinae.

Genus ***ICRIOMA*** De Wever, 1979.

Type species: Icrioma tetrancistrum De Wever, 1979 in De Wever *et al.,* 1979.

Original description: (of De Wever, 1979 p. 85) Capnuchosphaerids with four arms having a regular, loosely spongy structure.

Range: Upper Triassic (upper Carnian-Norian).

Occurrence (literature): Oregon, California, Alaska, Europe, Middle East, Japan.
Occurrence (this study): West Timor, Indonesia.

Remarks: Icrioma differs from *Capnuchosphaera* De Wever, 1979 by having four, rather than three tumidaspinae and from *Catoma* Blome, 1983 by possessing tumidaspinae.

Icrioma sp. aff. ***I. tetrancistrum*** De Wever, 1979.
Pl. 7, figs. 3, 7.
Cat. No. 3074/17.

aff.*1979 *Icrioma tetracistrum* De Wever in De Wever *et al.,* 1979 p. 86, Pl. 4, figs. 13-15.

Original description: (of De Wever, 1979 p. 86) Sphere with four projections disposed in approximately tetrahedral axes. The cortical shell is subspherical, without a medullary shell, and has pores forming a meshwork which is slightly spongy. The four projections are prolongations of the spongy shell wall, and thus cause angular distortion of the sphere. The spongy columnar projections are terminated in a triangular flare. The distal distal triangular part is formed mainly of three rods from each of which arises a distally directed blade. These blades join in the axis of the projection and produce a terminal point, and their margins are thickened.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	119	122	117
Total length of arms	118	120	114

Material: 15 specimens

Range: Upper Triassic (upper Carnian-Norian).

Occurrence (literature): Sicily, Turkey.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246, 223).

Remarks: Icrioma tetrancistrum differs from other species of *Icrioma* by having tumidaspinae with triangular flaring lamellae.

Genus ***KAHLEROSPHAERA*** Kozur and Mostler, 1979.

Type species: Kahlerosphaera parvispinosa Kozur and Mostler, 1979

Original description: (of Kozur and Mostler, 1979 p. 64) Kugelige, sehr feinporige, im lichtmikroskop fast dicht erscheinede einfache Schale mit 3 kraftigen hauptstacheln die etwas langer als der aussere kugel durchmeisser sind, sie sind dreikantig und distal mit

3 kraftigen seitenstacheln besetzt, die von den kanten der hauptstacheln ausstrachen. In fortsetzung der hauptstacheln befindet sich nach der abzweigung der neben stacheln ein schlanker Dorn. Auf dem proximalteil der seitenstacheln sitzt je ein Dorn Unterscheidlicher lange. In fortsetzung der 3 hauptstacheln sind kleine nadel formige innere stacheln ausgebildet. Eine markschale wurdenicht beobochtet.

Range: Upper Triassic (Carnian and Norian).

Occurrence (literature): Oregon, Philippines, Central Japan.
Occurrence (this study): W. Timor, Indonesia.

. . . .

Remarks: (of Blome, 1988 p. 745) The genus *Kahlerosphaera* differs from all other Triassic three-spined spumellarians by possessing primary spines which are triradiate in axial section each with four secondary spines that are not in the same plane.

Kahlerosphaera aspinosa Kozur and Mostler, 1981.
Pl. 11, figs. 1, 2.
Cat. Nos. 3073/35, 3073/22.

*1981 *Kahlerosphaera* (?) *aspinosa* Kozur and Mostler in Kozur and Mostler, p. 36, Pl. 47, fig. 3.

Original description: (of Kozur and Mostler, 1981 p. 36) Schale subspharisch bis subtriangular, spongios. Proximaler Teil der kraftigen Stacheln kurz, dreikantig. Distaler Teil der Hauptstacheln mit drei nach innen geneigten Seitenstacheln, die einen langeren Abshnitt an den Kanten der Haupstacheln in Richtung auf die lange Distalspitze hochlaufen, wodurch eine pfeilartige Seitenansicht entsteht.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of arms	148	158	119
Diameter of cortical shell	84	89	70
Length of secondary spines	78	82	50

Material: 8 specimens

Range: Upper Triassic (Norian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246, 232).

Remarks: K. aspinosa Kozur and Mostler, 1981 differs from other species of *Kahlerosphaera* by having secondary spines which are subtriangular in outline.

Kahlerosphaera norica Kozur and Mostler, 1981.
Pl. 11, fig. 3.
Cat. No. 3026/26.

*1981 *Kahlerosphaera norica* Kozur and Mostler in Kozur and Mostler, 1981, p. 36, Pl. 15, fig. 4.

Original description: (of Kozur and Mostler, 1979 p. 36) Ussere Schale subspharische bis subtriagular, zweischichtig. Gitterkreuzungspunkte des usseren Gitters mit spitzen Knatchen oder kurzen Dornen. Die 3 Arme sind dreikantig. Distalzweigt von jeder Kante je ein sehr langer, etwas nach aussen gebogener Seitenstacheln ab. Zentral laufen die drei Hauptstacheln in einen kurzen Dorn aus.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of arms	136	140	134
Diameter of cortical shell	72	75	70
Length of secondary spines	109	141	82

Material: 21 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 231).

Remarks: Kahlerosphaera norica differs from other species of the genus by having slim, tapering secondary spines which curve away from the cortical shell.

Kahlerosphaera sp. A.
Pl. 11, fig. 4.
Cat. No. (3251/3 = Holotype fig. 4).

Diagnosis: A species of *Kahlerosphaera* distinguished by the bladed extensions on each ridge of the arms.

Description: Cortical shell moderate size, subcircular in outline. Meshwork comprises of variably sized, subcircular pores surrounded by polygonal pore frames, with variably sized nodes at the pore frame vertices. Primary spines consisting of a proximally, thick, short, triradiate shaft which is untwisted and each ridge bifurcates at the point of attachment to the cortical shell; the medial section of each primary spine consists of three wide, axehead shaped blades extending from each ridge with two saddles along the outer surface of the blade. The distal part of the spinal shaft consists of a very long, straight spine which is circular in axial section, comprising of half to two thirds of the length of any given primary spine.

Dimensions (microns):	Average of 10 specimens	max.	min.	Holotype
Length of arms	257	288	220	273
Diameter of cortical shell	151	161	139	142
Length of secondary spines	84	97	62	87

Material: 49 specimens

Range: Upper Triassic (Carnian/Norian, as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223, 232).

Remarks: Kahlerosphaera petalouda n. sp. differs from *K. philippinensis* Yeh, 1990 by having primary spines with no torsion and by having wide medial bladed spines with concave outer edges. This species is also similar to *Kahlerosphaera longispinosa*

(Kozur and Mostler, 1979 Pl. 14, fig. 7), but differs by having the secondary spines situated half way along the primary spines.

Kahlerosphaera sp. aff. ***K. aspinosa*** Kozur and Mostler, 1981
Pl. 11, figs. 6, 7.
Cat. Nos. 3054/12, 3054/16.

aff.*1981 *Kahlerosphaera* (?) *aspinosa* Kozur and Mostler in Kozur and Mostler, p. 36, Pl. 47, fig. 3.

Original description: (of Kozur and Mostler, 1981 p.36) Schale subspharisch bis subtriangular, spongios. Proximaler Teil der kraftigen Stacheln kurz, dreikantig. Distaler Teil der Hauptstacheln mit drei nach innen geneigten Seitenstacheln, die einen längeren Abshnitt an den Kanten der Haupstacheln in Richtung auf die lange Distalspitze hochlaufen, wodurch eine pfeilartige Seitenansicht entsteht.

Dimensions (microns):	Average of 7 specimens	max.	min.
Length of arms	202	231	189
Diameter of cortical shell	131	140	128
Length of secondary spines	94	132	81

Material: 7 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 246).

Remarks: K. sp. aff. *K. aspinosa* Kozur and Mostler, 1981 differs from the holotype by having slightly longer primary spines.

?***Kahlerosphaera*** sp. aff. ***K. longispinosa*** Kozur and Mostler, 1979
Pl. 11, fig. 8.
Cat. No. 3073/16.

? aff.*1979 *Kahlerosphaera longispinosa* Kozur and Mostler in Kozur and Mostler, Pl. 14, figs. 3, 7.

Original description: (of Kozur and Mostler, 1979 p. 65) Mit den Gattungsmerkmalen. Schale sehr feinporig. Seitenstacheln sehr lang, schalenparallel etwas ruckgebogen, im proximalen Teil mit je einem langen, schrag nach aussen gerichteten Dorn besetzt. Zentraler Dorn in verlangerung der Hauptstacheln ebenfalls lang.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of arms	143	152	139
Diameter of cortical shell	156	161	149
Length of secondary spines	194	210	178

Material: 13 specimens

Range: Upper Triassic (Norian).

Occurrence (literature): Austria.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 232, 223).

Remarks: Kahlerosphaera sp. aff. *K. longispinosa* Kozur and Mostler, 1979 differs from *K. longispinosa* by having extremely long primary and secondary spines. Preservation of this form is poor and so the fourth spine has not been properly observed.

Kahlerosphaera sp. aff. ***K. norica*** Kozur and Mostler, 1981.
Pl. 11, figs. 5, 9.
Cat. Nos. 3026/13, 3054/7.

*aff.1981 *Kahlerosphaera norica* Kozur and Mostler, p. 36, Pl. 15, fig. 4.

Original description: (of Kozur and Mostler, 1981 p. 36) Ussere Schale subspharische bis subtriagular, zweischichtig. Gitterkreuzungspunkte des usseren Gitters mit spitzen Knatchen oder kurzen Dornen. Die 3 Arme sind dreikantig. Distalzweigt von jeder Kante je ein sehr langer, etwas nach aussen gebogener Seitenstacheln ab. Zentral laufen die drei Hauptstacheln in einen kurzen Dorn aus.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of arms	116	123	110
Diameter of cortical shell	169	148	211
Length of secondary spines	101	111	84

Material: 5 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 246).

Remarks: Kahlerosphaera sp.aff. *K. norica* differs from *Kahlerosphaera norica* by having slightly longer distal secondary spines.

Genus *SARLA* Pessagno, 1979.

Type species: Sarla prietoensis Pessagno, 1979 in Pessagno *et al.,* 1979

Original description: (of Pessagno, 1979 p. 174) Test as with family. Cortical shell spherical to subspherical with an outer layer of large, polygonal pore frames and an inner layer of much smaller polygonal pore frames. Three primary spines of alternating grooves and ridges, typically displaying torsion of grooves and ridges.

Range: Upper Triassic (lower Carnian to lower Norian).

Occurrence (literature): Western North America, Europe, Middle East, Japan.
Occurrence (this study): West Timor, Indonesia.

Remarks: Sarla differs from *Capnuchosphaera* De Wever, 1979 by lacking a tumidaspinae. Its spines, though often showing torsion of alternating ridges and grooves, are relatively simple in construction. *Sarla* differs from *Tripocyclia* Haeckel in possessing a double-layered cortical shell. Blome (1988 p. 746) remarked that when preservation is poor specimens of this genus may erroneously be assigned to the genus *Eptingium* Dumitrica, 1977.

Sarla longispinosum (Kozur and Mostler, 1979) **emend.** Blome, 1983.
Pl. 15, fig. 3.
Cat. No. 3057/18.

*1979 *Triactoma longispinosum* Kozur and Mostler, p. 59, Pl. 1, fig. 6, Pl. 11, figs. 3, 8, Pl. 12, fig. 6, Pl. 13, fig. 1.
1983 *Sarla longispinosum* (Kozur and Mostler, 1979) emend. Blome, p. 19, Pl. 3, figs.5, 7, 10, 18, Pl. 11 fig. 4.

Emended description: (of Blome, 1983 p. 19) Cortical shell moderate in size; spherical, consisting of outer layer of variably sized, raised polygonal (predominantly pentagonal and hexagonal) pore frames with circular to ovate pores; inner layer of cortical shell consisting of smaller polygonal pore frames with circular pores. Primary spines triradiate in axial section, consisting of three relatively wide grooves two to three times as wide as ridges proximally, grooves decreasing in width distally; ridges and grooves straight in character; distal tip in some primary spines circular in axial section. Length of spines approximately twice diameter of cortical shell.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	179	189	176
Length of arms	321	332	297

Material: 8 specimens

Range: Upper Triassic (upper Carnian middle Norian as far as known).

Occurrence (literature): Oregon, Europe.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 223).

Remarks: Sarla longispinosum differs from other species of *Sarla* by having long primary spines.

Genus *VINASSASPONGUS* Kozur and Mostler, 1979.

Type species: Vinassaspongus subsphaericus Kozur and Mostler, 1979

Original description: (of Kozur and Mostler, 1979 p. 65) Subspharische oder discoidale spongiose sehale mit 3 kraftigen Hauptstacheln in einer Ebene, deren 3 kanten spiral gedieht sind. Mindestens eine innere schale ist vorhanden. Sie liegt ziemlich nahe der ausseren schale und ist mit dieser durch zahlreiche kurze stutzbalken verbunden. Die kraftigsten inneren stacheln liegen in verlangerung der 3 Hauptstacheln.

Range: Upper Triassic (as far as known).

Occurrence (literature): Austria.
Occurrence (this study): W. Timor, Indonesia.

Remarks: This genus differs from *Sarla* Pessagno, 1979 by having a spongy cortical shell rather than polygonal pore frames, and by the wide ridges and grooves forming the rays which terminate in a spine.

Vinassaspongus sp. A
Pl. 4, fig. 6.
Cat. No. 3251/5.

Description: Cortical shell moderate to large in size, subspherical in outline. Meshwork spongy. Primary spines comprising of thick, strong and highly twisted ridge and deep grooves. The ridges and grooves are straight in the proximal part twist and become wider in the medial section and is finally drawn out into a spinal shaft which is circular in axial section.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	135	141	128
Length of arms	156	168	146

Material: 25 specimens

Range: Upper Triassic (upper Carnian-Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223, 246, 232).

Remarks: Vinassaspongus sp. A differs from *Vinassaspongus transitus* by having more robust ridges and deeper grooves which exhibit more torsion.

Vinassaspongus sp. B
Pl. 16, fig. 5.
Cat. No. 3026/1

Description: Cortical shell moderate in size, subspherical in outline. Meshwork spongy. Primary spines moderately long, show almost torsion in the area close to the cortical shell, with thick ridges and moderately deep grooves. The grooves and ridges flare out in the medial part of the spine to form a tumour and are drawn out into a spinal shaft which is circular in axial section, comprising less than half the length of any given primary spine.

Dimensions (microns):	Average of 4 specimens	max.	min.
Diameter of cortical shell	86	89	83
Length of arms	151	154	147

Material: 4 specimens

Range: Upper Triassic (upper Carnian-Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223).

Remarks: Vinassaspongus sp. B differs from other examples of *Vinassaspongus* (described herein) by having primary spines exhibiting almost no torsion.

Genus ***SPONGOSTYLUS*** Haeckel, 1882

Type species: Spongostylus hastatus Haeckel, 1887.

Spongostylus carnicus Kozur and Mostler, 1979
Pl. 16, figs. 8, 9.
Cat. Nos. 3251/7, 3251/30.

*1979 *Spongostylus carnicus* Kozur and Mostler in Kozur and Mostler, 1979 p. 56, Pl. 9, figs. 5, 6, 8.

Original description: "(of Kozur and Mostler, 1979 p. 56) Aussere schale spharisch, dickwandig, aus einem spongiosen dichten Geflecht aufgebaut. Polarstacheln sehr kraftig und lang (ca. doppelt so lang wie der aussere schalendurchmesser). Im kurzen proximalen teil sind die drei kanten nicht oder nur wenig spiralig gedreht. Im etwas breiten, stark. Mindestens die aussere halfte des distalen abschnitts beigung der beiden Polarstacheln in entgegengesetzte Richinnere stacheln aus gebildet Eine markschale wurde nicht beobachtet, istaber wahrscheinlich vohanden.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	207	225	183
Length of arms	385	407	350

Material: 27 specimens

Range: Upper Triassic (Carnian-Norian as far as known).

Occurrence (literature): West Carpathians.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223, 232, 216-217-218, 231).

Remarks: This species differs from others of the genus by exhibiting torsion of the primary spines as well as the grooves and ridges on the primary spines.

Family **SATURNALIDAE** Deflandre, 1953 **emend.** De Wever, 1984 **emend.** Dumitrica 1985.

Type genus: Saturnalis Haeckel, 1882.

Description: (of De Wever, 1984 english translation from De Wever and Origlia) Central shell spherical to subspherical surrounded by a ring (girdle) simple or multiple, with or without spines, flat or ribbed (carena). The ring supported by two polar rays plus, eventually, auxiliary and subsidiary rays. The two polar rays penetrate the shell to its innermost part; auxiliary and subsidiary rays - when present - stop somewhere in the shell or on its surface (their number varies).

Range: Upper Triassic-Upper Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included subfamilies: Palaeosaturnalinae Kozur and Mostler, 1981 Saturnalinae Deflandre, 1953.

Remarks: De Wever (1984) remarked that previous work concentrated on the structure of the shell (Yao, 1972; Dumitrica, 1975; Donofrio and Mostler, 1978 and Kozur, 1979) and that this part of the test was of little taxonomic value. Furthermore, the central shell is very often missing (either broken during deposition or lost during diagenesis) and so in practical terms is almost meaningless. The hierarchy of characters for this family, according to De Wever (1984) is: 1) polar or peripolar spines; 2) auxiliary rays present or not; 3) simple or multiple ring; 4) carena on ring present or not and/or no spine close to the polar axis.

Subfamily **SATURNALINAE** Deflandre, 1953 **emend.** De Wever, 1984.

Type genus: Saturnalis Haeckel, 1882.

Description (Emended version of De Wever (1984)): "Saturnalide possedant des pines peripolaires. Les pines de l'anneau sont en nombre et position variables, parfoischez une m me espece. L'anneau est simple ou multiple, plat ou caren , soutenu ou non par des rayons auxiliaires. L'anneau est circulaire, elliptique ou subangulaire.

Range: Triassic to Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Acanthocircus Squinabol, 1903 *Mesosaturnalis,* Kozur and Mostler, 1981 *Kozurastrum,* De Wever, 1984 *Parasaturnalis,* Kozur and Mostler, 1972 *Saturnlis,* Haeckel, 1882.

Remarks: This subfamily differs from the Palaeosaturnalinae by containing spines which are non polar.

Genus *KOZURASTRUM* De Wever, 1984.

Type species: Spongosaturnalis minoensis Yao, 1972.

Original diagnosis: (of De Wever, 1984) Saturnalinae pouvru de rayons auxiliaires et/ou subsidiaires; pourvu ou non d'une car ne sur l anneau.

Range: Upper Triassic to Lower Jurassic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs from *Acanthocircus* by the presence of auxiliary spines, from *Mesosaturnalis* by the presence of auxiliary spines, from *Parasaturnalis* by having a simple ring, from other saturnalids by the existance of peripolar spines. Carter (1993) noted that many of the forms assigned to this genus were previously assigned to *Praemesosaturnalis* Kozur and Mostler, 1983 and that the two genera were probably synonymous. *Kozurastrum* is used in this study because of the presence of peripolar spines with auxiliary spines.

Kozurastrum beattiense Carter, 1993.
Pl. 21, figs. 7, 8.
Cat. Nos. 3208/13, 3208/15.

1986 *Palaeosaturnalis* sp. C, in Kishida and Hisada, fig. 4, no. 3.
1990 *Saturnoshaera* sp. 1, in Carter, 1990, Pl. 1, fig. 6.
*1993 *Kozurastrum beattiense* Carter, p. 52, Pl. 4, figs. 7, 8.

Description: (of Carter, 1993 p. 52) Test with relatively wide, flat ring, circular to subcircular in outline. Twenty short tapering spines normally surround the periphery of ring (number observed to vary from 17 to 22). Polar rays long and narrow; auxiliary rays (2 to either side of polar axis) frequently almost equal in size to polar rays. Ring cavity circular to subcircular in outline.

Dimensions (microns):	Average of 8 specimens	max.	min.
Width of ring	39	49	32
Diameter of ring	359	372	347
Length of peripheral spines	29	21	42

Material: 33 specimens

Range: Upper Triassic (Rhaetian).

Occurrence: (literature): Queen Charlotte Islands, British Columbia, Japan.
Occurrence: (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 224).

Remarks: This species is similar to *Kozurastrum sandspitensis* Blome, 1984 and differs by having more peripheral spines and by having a smaller test.

Kozurastrum sandspitensis Blome, 1984.
Pl. 21, fig. 2.
Cat Nos. 3208/16.

*1984 *Pseudoheliodiscus sandspitensis* Blome in Blome, p. 25, Pl. 3, figs. 6, 7, Pl. 17, fig. 1.
1993 *Kozurastrum sandspitensis* Blome; Carter, p. 54, Pl.4, fig. 2

Original description: (of Blome, 1984 p. 25) Test with ring. Peripheral spines massive, short and broad; axial spines about the same length as the circumaxial spines; seven circumaxial spines either side of the polar axis. Ring cavity large; polar spines of medium length, one shorter than the other auxiliary spines slightly shorter than polar spines, two to either side of axis defined by polar spines.

Dimensions (microns):	Average of 8 specimens	max.	min.
Width of ring	44	52	38
Diameter of ring	325	335	320
Length of peripheral spines	93	117	76

Material: 47 specimens

Range: Upper Triassic (Norian and Rhaetian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 224).

Remarks: This species differs from *K. huxleyense* Carter, 1993 by having more peripheral spines and by having a broader ring.

Kozurastrum sp. aff. ***K. sandspitensis*** Blome, 1984.
Pl. 21 figs. 4, 5, 6, 9.
Cat. No. 3208/22, 3208/18, 3208/17, 3768/1.

aff.*1984 *Pseudoheliodiscus sandspitensis* Blome in Blome, p. 25, Pl. 3, figs. 6, 7, Pl. 17, fig. 1.
aff.1993 *Kozurastrum sandspitensis* Blome; Carter, p. 54, Pl.4, fig. 2

Original description: (of Blome, 1984 p. 25) Test with ring. Peripheral spines massive, short and broad; axial spines about the same length as the circumaxial spines; seven circumaxial spines either side of the polar axis. Ring cavity large; polar spines of medium length, one shorter than the other auxiliary spines slightly shorter than polar spines, two to either side of axis defined by polar spines.

Dimensions (microns):	Average of 10 specimens	max.	min.
Width of ring	31	37	20
Diameter of ring	332	344	326
Length of peripheral spines	78	84	73

Material: 52 specimens

Range: Upper Triassic (Norian and Rhaetian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample TR1, 220, 224).

Remarks: This species differs from the holotype of Blome (1984) by having six and seven peripheral spines either side of the polar axis.

Kozurastrum sp. A
Pl. 21, figs. 1, 3.
Cat. Nos.
3208/23, 3208/21.

Description: Test with moderately wide, flat ring, circular in outline. 11-12 long tapering spines surround the periphery of the ring. Ring cavity circular in outline with a relatively large cortical shell occupying most of the ring cavity.

Dimensions (microns):	Average of 10 specimens	max.	min.
Width of ring	49	56	42
Diameter of ring	319	325	315
Length of peripheral spines	148	164	139

Material: 42 specimens

Range: Upper Triassic (Rhaetian, as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 224).

Remarks: This species differs from *K. sandspitense* by having only 12 peripheral spines which are extremely long and tapering.

Kozurastrum sp. B
Pl. 21, fig. 10.
Cat. No. 3768/3.

Description: Test with ring. Ring broad, circular to subcircular. One long, very broad, bladed peripheral spines with a distinct central along the centre of each spine. Six peripheral spines to one side of the polar axis five to the other side.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	37	39	33
Diameter of ring	283	294	276
Length of peripheral spines	94	112	91

Material: 8 specimens

Range: Upper Triassic (Norian and Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 1, 224).

Remarks: This species is differs from others by having a very broad ring, broad and bladed peripheral spines with central ridges.

Kozurastrum sp. C
Pl. 21, fig. 11.
Cat. No. 3768/2.

Description: Ring moderately broad, subcircular and slightly flattened in a plane perpendicular to the polar axis. 16 peripheral spine, eight either side of the polar axis.

Dimensions (microns):	Average of 8 specimens	max.	min.
Width of ring	27	33	25
Diameter of ring	347	352	340
Length of peripheral spines	71	83	45

Material: 12 specimens

Range: Upper Triassic (Norian and Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 1, 224)

Remarks: *K.* sp. C differs from others species of this genus by having 16 peripheral spines on a sagital ring which is flattened in a plane perpendicular to the polar axis.

Subfamily **PALAEOSATURNALINAE** Kozur and Mostler, 1981 **emend.** De Wever 1984.

Type genus: Palaeosaturnalis Donofrio and Mostler, 1978.

Definition: (of De Wever, 1984 p. 15) Saturnalidae with polar spines; position and number of other spines of the ring varies, even for same species. Ring single or multiple, supported or not supported by auxiliary rays.

Range: Triassic to Lower Jurassic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Heliosaturnalis Kozur and Mostler, 1972 *Paleosaturnalis* Donofrio and Mostler, 1978 *Pseudoheliodiscus* Kozur and Mostler, 1972.

Remarks: The crucial feature of this subfamily is the possession of polar spines.

Genus ***PALAEOSATURNALIS*** Donofrio and Mostler, 1978 **emend**. De Wever, 1984

Type species: Spongosaturnalis triassicus Kozur and Mostler, 1972.

Definition: (of De Wever, 1984 p. 15) Palaeosaturnalinae with a single ring, without auxiliary or subsidiary rays.

Range: Upper Triassic (Carnian)-Lower Jurassic (Hettangian).

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus (according to Kozur and Mostler, 1990) gives rise to *Liassosaturnalis* Kozur and Mostler, 1990 in the lower Hettangian. Pessagno (1979) followed by De Wever (1981) placed the type species of *Palaeosaturnalis* Donofrio and Mostler, 1978 in *Acanthocircus* Squinabol, 1903, however, the ring and especially the ring cross-section in *Acanthocircus* is different. De Wever (1984 p. 15) again emended this genus and it is this definition that is used here.

Palaeosaturnalis burnensis (Blome, 1984)
Pl. 18, fig. 1, Pl. 19, fig. 3.
Cat. Nos. 3020/30, 3056/9.

*1984 *Acanthocircus burnensis* Blome in Blome, 1984 p. 21, Pl. 1, fig. 1, 11.

Original description: (of Blome, 1984 p. 21) Test with relatively wide ring, hexagonal in outline. Peripheral spines narrow, long and broad; axial spine approximately the same length as circumaxial spines; six circumaxial spines, three to either side of axis defined by axial and polar spines. Ring cavity subcircular in outline; polar spines long and narrow.

Dimensions (microns):	Average of 8 specimens	max.	min.
Width of ring	35	37	32
Length of polar spines	158	167	144
Diameter of ring cavity	193	209	187

Material: 12 specimens

Range: Upper Triassic (Carnian-middle Norian).

Occurrence (literature): Western North America.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 228, 224, 216-217-218).

Remarks: This species differs from others by having a ring that is hexagonal in outline with three spines either side of the axis.

Palaeosaturnalis latiannulatus Kozur and Mostler, 1983
Pl. 17, figs. 3, 5, 6.
Cat. Nos. 3074/2, 3074/1.

*1983 *Palaeosaturnalis latiannulatus* Kozur and Mostler in Kozur and Mostler, p. 20, Pl. 5, fig. 1.

Original description: (of Kozur and Mostler, 1983 p. 20) Ring circular to subcircular, very broad, entirely flat and undifferentiated. Outer margin with only four long spines. Two spines are situated opposite to the two polar spines, the other two are perpendicular to these spines. At least four spongy cortical shells are present.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	48	59	43
Length of polar spines	112	119	98
Diameter of ring cavity	139	147	133

Material: 6 specimens
Range: Upper Triassic (lower-middle Norian).

Occurrence (literature): West Carpathians.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223, 231).

Remarks: This species differs from *Palaeosaturnalis raridenticulatus* by having a considerably wider ring. There appears to be a continuous gradation between *P. latiannulatus, P. raridenticulatus* and *Acanthocircus rotundus* with the only difference being the thickness of the ring.

Palaeosaturnalis ovalis n. sp.
Pl. 18, figs. 4, 10.
Cat. No. 3056/11 = Holotype = fig. 4, 10.

Diagnosis: A species of *Palaeosaturnalis* distinguished by its oval shaped sagital ring

Description: Test with broad ring, which is approximately oval in outline. Peripheral spines narrow, long and tapering; axial spines are approximately the same length as the circumaxial spines. Four circumaxial spines two either side of the axis as defined by the axial and polar spines. Internal cavity of the ring approximately oval in outline.

Dimensions (microns):	Average of 8 specimens	max.	min.	Holotype
Width of ring	55	62	51	56
Length of polar spines	147	165	128	165
Diameter of ring cavity	205	217	202	206

Material: 12 specimens

Range: Upper Triassic (Norian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232).

Etymology: Ovalis refers to the shape of the sagital ring.

Type locality: River Meto sections, near Soe, West Timor, Sample 232 (see Chapter 4 log sections).

Remarks: This species differs from other species of *Palaeosaturnalis* by possessing a broad oval ring with four circumaxial spines.

Palaeosaturnalis raridenticulatus Kozur and Mock, 1981.
Pl. 17, figs. 1, 2, 4.
Cat. Nos. 3027/30, 3056/5, 3276/1.

*1981 *Palaeosaturnalis raridenticulatus* Kozur and Mostler in Kozur and Mostler, p. 56, Pl. 61, fig. 5.
1984 *Acanthocircus rotundus* Blome, p. 24, Pl. 2, figs. 4, 5, 15.

Original description: (of Kozur and Mock, 1981 p. 56) Ring breit, flach. Zwei kraftig Polarstacheln gegenuber von Randstacheln. Senkrecht zu diesen Randstacheln befinden sich zwei weitere kraftige Randstacheln. Im Bereich der Randstacheln ist der Ring etwas verbreitert. Schale unbekannt, wohl spongios.

Dimensions (microns):	Average of 10 specimens	max.	min.
Width of ring	40	41	37
Length of polar spines	141	157	120
Diameter of ring cavity	122	125	118

Material: 71 specimens

Range: Upper Triassic (lower-middle Norian).

Occurrence (literature): West Carpathians.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 231, 223, 246, 239, 216-217-218).

Remarks: This species has a slightly broader ring and longer, more massive spines than the holotype of Kozur and Mostler, 1981. *Acanthocircus rotundus* Blome, 1984 is regarded as a junior synonym of *P. raridenticulatus* again the ring is much narrower than in the specimen reported here.

Palaeosaturnalis supleensis Blome, 1984.
Pl. 18, figs. 3, 5, 6, 8, 9.
Cat. Nos. 3056/12, 3056/7, 3056/13.

*1984 *Acanthocircus supleensis* Blome in Blome, p. 25, Pl. 2, figs. 7, 17.

Description: (of Blome, 1984 p. 25) Test with wide ring, elliptical in outline. Peripheral spines massive, long and broad; axial spines slightly more massive and sometimes longer when compared with the circumaxial spines; ten circumaxial spines, five either side of the axis defined by axial and polar spines. Ring cavity elliptical in outline; polar spines long and broad.

Dimensions (microns):	Average of 10 specimen	max.	min.
Width of ring	37	41	34
Length of polar spines	108	110	106
Diameter of ring cavity	136	141	130

Material: 22 specimens

Range: Upper Triassic (upper Carnian?-lower to middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 246, 223).

Remarks: P. supleensis differs from *P. Usitatus* by possessing a broad rather than narrow ring.

Palaeosaturnalis sp. aff. ***P. liassicus*** Kozur and Mostler, 1990.
Pl. 19, figs. 1, 10.
Cat. No. 3056/19.

aff.*1990 *Palaeosaturnalis liassicus* Kozur and Mostler in Kozur and Mostler, p. 192, Pl. 1 figs. 2, 3, Pl. 12, figs. 1, 3, 4, 6, 8, 10, Pl. 13, figs. 1, 2.

Original description: (of Kozur and Mostler, 1990 p. 192) Shell spongy, consisting of several concentric layers. Microsphere latticed. Shell surface with numerous short, needle-like spines. Ring narrow, flat, undifferentiated. Ring outline variable, mostly transversly elliptical to subrectangular, but few specimens are transversly elliptical to subrectangular, few others round to subquadratic, subcircular or slightly subelliptical with long axis parallel to polar spines. 11-13 mostly 12 very long needle-shaped spines, exceptionally single spines are terminally broadened or bifurcated.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	35	38	32
Length of polar spines	120	145	102
Diameter of ring cavity	153	162	146

Material: 6 specimens

Range: Upper Triassic (Norian) to Lower Jurassic.

Occurrence (literature): Europe, Japan.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 246).

Remarks: The desciption of Kozur and Mostler (1990) for this species allows for variation in the number of peripheral spines (11-13). *P. liassicus* differs from *P. supleensis* by having a narrow ring. Kozur and Mostler (1990) describe this species from the Liassic, whereas specimens recovered during this study are from the Upper Triassic (Norian).

Palaeosaturnalis sp. aff. ***P. mocki*** Kozur and Mostler, 1983
Pl. 19, fig. 7.
Cat. No. 3020/25.

aff*1983 *Palaeosaturnalis mocki* Kozur and Mostler in Kozur and Mostler, p. 21, Pl. 5, fig. 2.

Original description: (of Kozur and Mostler, 1983 p. 21) Ring broad, circular, entirely flat and undifferentiated. Outer margin with eight spines. Two spines opposite to the two polar spines and two, about perpendicular to the polar spines, are a little larger yhan the other four spines. Always one of these smaller spines is situated between the larger ones.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	32	39	28
Length of polar spines	103	115	93
Diameter of ring cavity	118	120	111

Material: 6 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (literature): West Carpathians.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: This species differs from *P. latiannulatus* by having eight, as oppossed to four peripheral spines. This form differs from the holotype of Kozur and Mostler (1983) by having a less broad ring.

Palaeosaturnalis sp. aff. ***P. usitatus*** Blome, 1984.
Pl. 19, fig. 8.
Cat. No. 3027/27.

aff.*1984 *Acanthocircus usitatus* Blome in Blome, p. 25, Pl. 2, fig. 8, 18.

Original description: (of Blome, 1984 p. 25) Test with narrow ring, elliptical in outlline. Peripheral spines massive; axial spines appreciably longer than circumaxial spines; twelve circumaxial spines, five to either side of axis defined by axial and polar spines. Ring cavity elliptical in outline.

Dimensions (microns):	Average of 8 specimens	max.	min.
Width of ring	31	38	25
Length of polar spines	176	183	170
Diameter of ring cavity	138	148	132

Material: 8 specimens

Range: Upper Triassic (upper Carnian?-lower to middle Norian).

Occurrence (literature): Oregon.

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Palaeosaturnalis sp. aff. *usitatus* Blome, 1984 differs from *Acanthocircus supleensis* Blome, 1984 by having a narrower ring, and from *A. fluegeli* Kozur and Mostler, 1972 by having an elliptical ring. This form differs from the holotype of Blome (1984) by having an elliptical ring parallel to the polar spines.

Palaeosaturnalis sp. A
Pl. 18, figs. 2, 7, Pl. 19, fig. 2.
Cat. No. 3020/33, 3056/18.

Description: Cortical shell spongy, spherical to subspherical; ring broad, flat and subcircular in outline, polar spines axial longer than other peripheral spines; eight peripheral spines four either side of polar and axial spines.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	29	32	27
Length of polar spines	98	109	89
Diameter of ring cavity	158	164	152

Material: 6 specimens

Range: Upper Triassic (lower-middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Palaeosaturnalis sp. A differs from *Acanthocircus* sp. D of Blome, 1984 by having a more circular ring outline and by having less massive peripheral spines.

Palaeosaturnalis sp. B
Pl. 19, figs. 4, 11.
Cat. No. 3074/4.

Description: Ring and ring cavity subcircular to elliptical in outline; ring broad flat with 12 subtriangular peripheral spines, the two axial spines are approximately the same length as other peripheral spines.

Dimensions (microns):	Average of 5 specimens	max.	min.
Width of ring	34	36	31
Length of polar spines	42	45	39
Diameter of ring cavity	120	128	113

Material: 5 specimens

Range: Upper Triassic (lower Norian).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: This species differs from others of the genus *Paleosaturnalis* by having peripheral spines which are subtriangular in shape and approximately all the same size.

Palaeosaturnalis sp. C
Pl. 19, fig. 6.
Cat. No. 3027/28.

Description: Ring very broad, flat with broad polar spines. Peripheral spines (12) subtriangular in shape and approximately the same size.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	44	47	40
Length of polar spines	66	83	51
Diameter of ring cavity	115	120	102

Material: 11 specimens

Range: Upper Triassic (Norian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 246).

Remarks: This species differs from *Acanthocircus supleensis* Blome, 1984 by having short subtriangular peripheral spines which are approximately the same length.

Palaeosaturnalis sp. D
Pl. 19, figs. 5, 9.
Cat. No. 3027/31, 3020/22.

Description: Ring moderately broad subcircular to elliptical in outline. Four axial spines on the peripheral part of the ring much longer than other peripheral spines. Fifteen peripheral spines in total, circumaxial spines moderately short and tapering. Cortical shell large, spherical and occupies most of the central ring cavity.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	30	33	26
Length of polar spines	162	173	156
Diameter of ring cavity	152	168	148

Material: 11 specimens

Range: Upper Triassic (Norian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232).

Remarks: This species differs from *Acanthocircus usitatus* Blome, 1984 by having more peripheral spines and by having much longer axial spines.

Genus ***PSEUDOHELIODISCUS*** Kozur and Mostler, 1972 **emend.** De Wever, 1984.

Type species: Pseudoheliodiscus riedeli Kozur and Mostler, 1972.

Original definition: (of De Wever, 1984): Auxiliary spines and polar spines as with subfamily (two opposed polar spines, and a variable number of auxiliary spines. Auxiliary spines connected with periphery of discoidal, spongy cortical shell); length of polar spines and auxiliary spines varying with species. Ring single with peripheral spines.

Range: Upper Triassic (Carnian) to Middle Jurassic.

Occurrence (literature): Worldwide.

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia.

Remarks: Pseudoheliodiscus Kozur and Mostler, 1972 differs from *Heliosaturnalis* Kozur and Mostler, 1972 by having a single ring, and from *Palaeosaturnalis* Donofrio and Mostler, 1978 by having auxiliary spines. De Wever (1984) emended the definition and it is this definition which is used herein.

Pseudoheliodiscus carteri n. sp.
Pl. 20, figs. 1, 2, 3, 10.
Cat. Nos. 3056/3 = Holotype figs. 1, 10, Paratypes =3056/6, 3056/17 figs. 2, 3.

Diagnosis: A species of *Pseudoheliodiscus* distinguished by its large, undulating subquadratic sagital ring with 14 auxiliary spines.

Description: Cortical shell large, spongy, spherical to subspherical or subquadratic; ring very broad, undulating and subquadratic to quadratic in outline; the degree of undulation or folding of the ring edges determines the square appearance of the ring outline; four circumaxial peripheral spines are moderately long and tapering gradually; spines polar with a further 14 auxiliary spines which vary in size, all, however, much smaller than polar spines; outline of ring cavity circular.

Dimensions (microns):	Average of 10 specimens	max.	min.	Holotype
Width of ring	88	100	72	89
Length of polar spines	145	162	122	158
Diameter of ring cavity	167	182	125	175

Material: 10 specimens

Range: Upper Triassic (lower to middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Etymology: This species is named in honour of Dr. E. S. Carter for her work on Triassic radiolarians from the Queen Charlotte Islands, Canada.

Type locality: River Meto sections near Soe, West Timor, Sample 232 (see Chapter 4 log sections).

Remarks: Pseudoheliodiscus carteri n. sp. differs from others of this genus by having an extremely broad, undulating ring with a quadratic outline and by having 14 auxiliary spines.

Pseudoheliodiscus sp. A
Pl. 20, figs. 7, 11.
Cat. Nos. 3056/16, 3056/10.

Description: Cortical shell large, spongy and spherical in outline; ring broad, flat and subcircular to elliptical in outline; polar spine are distinguished (especially when cortical shell is present) by a slightly straight or flat area around their point of attachment to ring in the ring cavity; polar spines perpendicular to the long axis of the elliptical ring; two auxiliary spines present; four peripheral spines of equal length on the outer edge of the ring.

Dimensions (microns):	Average of 6 specimens	max.	min.
Width of ring	64	71	58
Length of polar spines	124	132	109
Diameter of ring cavity	192	196	189

Material: 6 specimens

Range: Upper Triassic (lower to middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Pseudoheliodiscus sp. A differs from other forms of *Pseudoheliodiscus* by having a flat, elliptical, as opposed to an undulating, subquadratic ring, in outline and by having only two auxiliary spines.

Genus *STAURACANTHOCIRCUS* Kozur and Mostler, 1983 **emend.** Kozur and Mostler, 1990

Type species: Pseudoheliodiscus concordis De Wever, 1981.

Emended description: (of Kozur and Mostler, 1990 p. 196) Typical form large. Shell spongy, globular or with rhombic or polygonal equatorial outline and subhemiglobular or somewhat flattened lower and upper side. Around the latticed microsphere several concentric or subconcentric layers of spongy meshwork are present; ring narrow, flat or with shallow elliptical cross-section, undifferentiated. Outline variable, mostly rectangular, quadratic, sometimes subelliptical, rarely roundish. Outer margin with many spines of different length. Two long polar spines and two to four long auxiliary are present. If there are two auxiliary spines, then they are always arranged in cross-like position with polar spines. If there are four auxilairy spines, they are diagonally arranged against the polar spines, but the midline of the two pairs of auxiliary spines lies again in a cross-like position with the polar spines. The auxiliary spines often become as strong as the polar spines. In this case four or six first order spines of the above mentioned arrangments are present.

Range: Upper Triassic (Norian) to Lower Jurassic (Toarcian).

Occurrence (literature): Greece, Sicily, Turkey, Oregon, Bavaria, Hungary.
Occurrence (this study): W. Timor, Indonesia.

Remarks: This genus is rare in the Norian and Rhaetian becoming more frequent in the Hettangian to Pliensbachian. It also appears that the older (Upper Triassic) forms of this genus generally have few peripheral spines which are larger than those observed in the Early Jurassic and have broader a ring.

?***Stauracanthocircus tozeri*** n. sp.
Pl. 20, fig. 4, 5, 6, 8, 9.
Cat. Nos. 3056/2 = Holotype fig. 5, Paratypes =3027/29, 3056/21, 3020/20, 3276/3, figs. 4, 6, 8, 9.

Diagnosis: This species of *Stauracanthocircus* is distinguished from others by a subquadratic sagital ring with 13-16 peripheral spines.

Description: Cortical shell spongy and spherical to quadratic in outline. Ring relatively broad, flat, subquadratic in outline at and may be approximately 45 degrees around from the position of the cortical shell. Thirteen to sixteen peripheral spines, axial spines noticeably longer, with the peripheral polar spines even larger. Two or three cicumaxial peripheral spines between axial spines. Peripheral spines generally short and tapering.

Dimensions (microns):	Average of 10 specimens	max.	min.	Holotype
Width of ring	29	33	25	31
Length of polar spines	84	110	67	103
Diameter of ring cavity	235	241	226	233

Material: 10 specimens

Range: Upper Triassic (lower-middle Norian as far as known).

Occurrence (this study): Noil Meto,Soe, W. Timor, Indonesia (Sample 232).

Etymology: This species is named after E. T. Tozer in honour of his work in Triassic stratigraphy.

Type locality: River Meto sections, West Timor, Sample 232 (see Chapter 4 log sections).

Remarks: ?S. tozeri n. sp. differs from others species of *Stauracanthocircus* by having a broader ring with tapering peripheral spines, which vary in number (13-16) and are longer in the axial positions. The genus *Stauracanthocircus* is questioned here as it is possible to assign it to the genus *Pseudoheliodiscus* using the taxonomic system of De Wever (1984). The central cortical shell is a character used in the definition of the genus and according to De Wever (1984) is not particularly useful taxonomically as it is often missing. All forms recovered during this study possessed the central cortical shell and so obscured the identification of the polar spine. The reason for placing this form within the genus *Stauracanthocircus* is that the overall ring shape (narrow and quadratic) is similar to forms illustrated by Kozur and Mostler (1990).

Genus ***ORBICULIFORMA*** Pessagno, 1973

Type species: Orbiculiforma quadrata Pessagno, 1973

Original description: (of Pessagno, 1973 p. 71) Test circular to square in outline with short peripheral spines. Center of test markedly depressed; central cavity flanked by prominent rim. Central cavity occassionally obscured by fragile secondary meshwork.

Range: Upper Triassic-Upper Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Orbiculaforma differs from other Mesozoic spumellaria by having a disc-shaped spongy test with concentric arrangement throughout and central cavities on opposing sides of the test Blome (1988). *Perispongidium* Haeckel, 1881 as described by De Wever (1979) is possibly, but may not be synonymous with *Orbiculaforma*, as the specimens described did not have central areas with cavities present.

Orbiculaforma sp A .
Pl. 11, fig. 11, Pl. 15, figs. 10, 11, 12.
Cat. Nos. 3054/24 = Holotype fig. 11, Paratypes =3054/17, 3054/21, 3054/8, Pl. 15, figs. 10, 11, 12.

Diagnosis: A species of *Orbiculiforma* distinguished by a narrow periphery with a large central depression.

Description: Test wide, peripheral rim narrow and circular to subcircular in outline with large central depression; meshwork not arranged radially; eight to twelve peripheral spines; spines are flattened in the plane parallel to the crown the inner part of the crown is more spongy in nature.

Dimensions (microns):	Average of 10 specimens	max.	min.	Holotype
Diameter of test	375	356	404	363
Width of rim	64	73	47	62
Length of peripheral spines	23	35	19	22

Material: 16 specimens

Range: Upper Triassic (lower Norian).

Occurrence (this study): Noil meto, Soe, W. Timor, Indonesia (Sample 232, 231, 223).

sections).

Remarks: Orbiculaforma kyklica n. sp. differs from *Orbiculaforma tethyus* by having a wider crown and by having a spongy central area and less well-arranged pores and pore frames, and differs from *O. cedrosensis* Pessagno, 1979 by having a circular rather than an octagonal outline. *O. kyklica* n. sp. differs from *Praeorbiculiforma goestlingensis* Kozur and Mostler, 1978 and *P. vulgaris* Kozur and Mostler, 1978 by having smaller peripheral spines and irregular pores around the rim.

Orbiculaforma tethyus De Wever, 1979
Pl. 11, figs. 10, 12.
Cat. Nos. 3054/29, 3100/16.

*1979 *Perispongidium tethyus* De Wever in De Wever *et al.*, p.94, Pl. 7, figs. 6-8.

Original description: (of De Wever, 1979 p. 94) Crown with spines on the external margin. Thre crown, circular in axial section, is spongy throughout, with sub-rectangular meshes arranged in regular concentric series. The external side of the crown bears eight to ten spines. These spines are triangular and flattened in the plane of the crown, showing pores in this plane. They are disposed more or less regularly around the crown, and vary a little in length and width. The inner part of the crown shows a velum with rectangular pores disposed in circular rows and quincunxes.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of test	280	295	271
Width of rim	78	89	72
Length of peripheral spines	54	97	38

Material: 22 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (literature): Greece.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 233-234, 231, 223).

Remarks: This species differs from *O. cedrosensis* Pessagno, 1979 by having more regularly arranged meshwork of larger pores around the crown.

Subfamily **TRIARCELLINAE** Kozur and Mostler, 1981.

Original description: (of Kozur and Mostler, 1981 p. 26) Aussere Schale klein, mit subcicularem Umriss. Sie ist spongios bis zweischictig gegitter mit kleinen inneren und etwas grosseeren ausseren Poren. InnereSchalenmerkmale wenig bekannt. Markschale anscheinend vorhanden. Es treten drei dreikantige Arme auf. Zwei der Kanten sind durch einen Ring, ahnlich demjenigen der Saturnalidae, ensteht. Von der dritten Kante geht ein Stachel oder ein senkrecht zum Hauptring verlaufender kurzer Bogen aus.

Range: Upper Triassic (as far as known).

Occurrence (literature): Slovakia.
Occurrence (this study): West Timor, Indonesia.

Included genera: Triarcella, Kozur and Mostler, 1981.

Remarks: This subfamily consists of the genus *Triarcella* and is distinguished from other saturnalid families by having three spines supporting the sagital ring.

Genus ***TRIARCELLA*** Kozur and Mostler, 1981

Type species: Triarcella sulovensis Kozur and Mosler, 1981

Original description: (Genus and species description of Kozur and Mostler, 1981 p. 26) Schale klein, mit subcircularem bis subtriangularem Umriss, spongi s bis zweischichtig gegittert. Markschale vorhanden. Die drei Hauptstacheln sind kraftig unddreikantig. Von je zwei kanten geht distal ein ovaler Bogen aus, der mit den Distalenden von je zwei Seitenkanten der benachbarten Bogen verbunden ist. Dadurch ensteht ein geschlossener Ring, der zwischen den Haupstacheln jeweils etwas nach aussen gebogen ist. Dieser Ring kann an seinen am starksten gebogenen Teilen aussen kleine stacheln tragen, die aber sehr zart und daher meist abgebrochen sind. Die drei Haupstacheln laufen jeweils in einen knotenartigen Forstatz aus, der den Ring etwas uberragt. Die jeweils dritte kante der Haupstacheln, die nicht durch einen Bogen mit den anderen Haupstacheln verbunden ist, lauft distal in einen zarten Dorn aus, der meist abgebrochen ist.

Range: Upper Triassic (as far as known).

Occurrence (literature): Slovakia.
Occurrence (this study): Soe, W. Timor, Indonesia.

Remarks: This genus differs from other genera within the Saturnalinae by not having polar and auxilliary spines attaching the cortical shell to the ring, but three bladed and grooved arms from the cortical shell to the ring.

Triarcella sulovensis Kozur and Mostler, 1981.
Pl. 17, fig. 11.
Cat. No. 3747/9.

* 1981 *Triarcella sulvensis* Kozur and Mostler in Kozur and Mostler, Pl. 62, figs. 1-4.

Original description: (Genus and species description of Kozur and Mostler, 1981 p. 26) Schale klein, mit subcircularem bis subtriangularem Umriss, spongios bis zweischichtig gegittert. Markschale vorhanden. Die drei Hauptstacheln sind kraftig unddreikantig. Von je zwei kanten geht distal ein ovaler Bogen aus, der mit den Distalenden von je zwei Seitenkanten der benachbarten Bogen verbunden ist. Dadurch ensteht ein geschlossener Ring, der zwischen den Haupstacheln jeweils etwas nach aussen gebogen ist. Dieser Ring kann an seinen am starksten gebogenen Teilen aussen kleine stacheln tragen, die aber sehr zart und daher meist abgebrochen sind. Die drei Haupstacheln laufen jeweils in einen knotenartigen Forstatz aus, der den Ring etwas uberragt. Die jeweils dritte kante der Haupstacheln, die nicht durch einen Bogen mit den anderen Haupstacheln verbunden ist, lauft distal in einen zarten Dorn aus, der meist abgebrochen ist.

Dimensions (microns):	Average of 8 specimens	max.	min.
Width of ring	13	15	12
Length of auxiliary spines	31	34	28
Diameter of ring cavity	166	172	161

Material: 10 specimens

Range: Upper Triassic (as far as known)

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 246, 223).

Remarks: This specimen is very similar to *Triarcella sulovensis* Kozur and Mostler, 1981, however, the cortical shell is proportionally larger when compared with the ring of the type species, and the cortical shell is slightly more spherical, these, however, may be a feature of preservation. This species also differs from *Triarcella arcuata* Kozur and Mostler, 1981 by having a less triangularly-shaped ring.

Genus *HELIOSOMA* Haeckel 1882 **emend.** Kozur and Mostler, 1979.

Original description: (of Kozur and Mostler, 1979 p. 50-51) Ussere schale polygonal-subsparische, gegittert. Die 14 ka ftigen Hauptstacheln sind basal stets breit und kr ftige dreikantig, wobei der Bereich Zwischen den kanten tief eingesenht ist. Teils bleiben die stacheln auf ihrer ganzen Lange kraftige dreikantig, teils sind ihre Enden nadelformig ausged. Zwischen den Hauptstacheln laufen, von deren seitenkantenbasis ausgehend, unterschiedlich stark ausgebildete. Rippen, wobei von jeder Kantenbasis 1-2 Rippen ausgehend. Die hauptsacheln setzen sich nach innen in haarf rmigen, Z. T. etwas gebogenen stacheln, die wegen ihrere Zartheit meist abgebrochen sind, bis nahe zum zentrum hin fort, Eine sehr kleine, zarte, bei dem vorliegenden material stets nur in Resten erhatene markschale ist vorhanden.

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus appears to have saddles connecting the spines on the cortical shell.

Heliosoma sp. aff. ***H. carinata*** Kozur and Mostler, 1979.
Pl. 14, fig. 10.
Cat. No. 3214/9.

*1979 *Heliosoma carinata* Kozur and Mostler in Kozur and Mostler, p. 50-51, Pl. 9, figs. 1-3.
1984 *Heliosoma carinata* Kozur and Mostler, Lahm, Pl. 9, fig. 8

Original description: (of Kozur and Mostler, 1979 p. 50-51) Ussere schale polygonal-subspharische, gegittert. Die 14 kraftigen Hauptstacheln sind basal stets breit und kraftige dreikantig, wobei der Bereich Zwischen den kanten tief eingesenht ist. Teils bleiben die stacheln auf ihrer ganzen Lange kraftige dreikantig, teils sind ihre Enden nadelformig ausgedunnt. Zwischen den Hauptstacheln laufen, von deren seitenkantenbasis ausgehend, unterschiedlich stark ausgebildete. Rippen, wobei von jeder Kantenbasis 1-2 Rippen ausgehend. Die hauptsacheln setzen sich nach innen in haarformigen, Z. T. etwas gebogenen stacheln, die wegen ihrere Zartheit meist abgebrochen sind, bis nahe zum zentrum hin fort, Eine sehr kleine, zarte, bei dem vorliegenden material stets nur in Resten erhatene markschale ist vorhanden.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of spines	31	48	23
Diameter of central shell	202	208	198

Material: 31 specimens

Range: Upper Triassic (Carnian-Norian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 231, 232, 246).

Remarks: This species is characterised by having a test covered in bars connecting the the spines which tend to differ from the holotype of Kozur and Mostler, 1979 by having more bars.

Heliosoma sp. aff. ***H. mocki*** Kozur and Mostler, 1979
Pl. 14, figs. 11, 12, Pl. 16, figs. 11, 12.
Cat. Nos. 3026/10, 3073/6, 3054/23, 3026/12.

aff.*1979 *Acanthosphaera? mocki* Kozur and Mostler in Kozur and Mostler, p. 49-50, Pl. 7, fig. 1
aff.1984 *Heliosoma mocki* Kozur and Mostler, Pl. 11, fig. 6.

Original description: (of Kozur and Mostler, 1979 p. 49-50) Einfache, ziemlich grobporige Gitterschale mit 14 massig langen, basal sehr breiten dreikantigen

Hauptstacheln, die distal unter allmählicher Verschmälerung zugespitzt sind. Innere stacheln nadelformig, bei allen untersuchten Exemplaren kurz hinter ihrer Basis abgebrochen.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of spines	45	66	32
Diameter of central shell	117	127	109

Material: 31 specimens

Range: Upper Triassic (Carnian-Norian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246, 232, 223, 220).

Remarks: This species differs from the holotype of Kozur and Mostler, 1979 by having very large, triradiate (in axial section) spines.

Family **HEXAPOROBRACHIDAE** Kozur and Mostler, 1979.

Type genus: Hexaporobrachia Kozur and Mostler, 1979.

Original description: (for Family and Genus of Kozur and Mostler, 1979 p. 77) Von einer kugeligen, selten etwas polygolanen oder discoidalen gegitterten, selten spongiösen schale gegen 4, 6 oder mehr gegitterte oder spongiose Arme aus, die in kraftigen stacheln enden. Innebau nur bei *Tetraporobrachia* , genau bekannt. In verlängerung der Arme sind. Kraftige innere stacheln vorhanden, die zu einer grossen inneren Schale verlaufen, die auch noch durch weitere stacheln mit der äusseren Schale verbunden ist. Die inneren stacheln in verlängerung der Arme setzen sich innerhalb der innere Schale fort und treffen sich in deren Zentrum.

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe, British Columbia.
Occurrence (this study): W. Timor, Indonesia.

Included genera: Hexapyramis Squinabol, 1903 *Hexaporobrachia* Kozur and Mostler, 1979 *Pentaporobrachia* Kozur and Mostler, 1981 *Tetraporobrachia* Kozur and Mostler, 1979.

Remarks: Included genera: *Hexapyramis* Squinabol, 1903, *Icrioma* De Wever, 1979, *Hexaporobrachia* Kozur and Mostler, 1979, *Tetraporobrachia* Kozur and Mostler, 1979. *Tetraporobrachia* appears to be restricted to the upper Norian/Rhaetian in samples from this study.

Genus ***PENTAPOROBRACHIA*** Kozur and Mostler, 1981.

Type species: Pentaporobrachia longispinosa Kozur and Mostler, 1981.

Original description: (of Kozur and Mostler, 1981 p. 23) Äussere Schale im Verhältnis zu den Armen klein, mit subpolygonalem bis subcircularem Umriss. 5 wuchtige Arme strahlen in unterschiedlichen Richtungen aus. Ihre breite Basis nimmt den grossten Teil der Schalenberflache ein. Äussere Schale spongios mit grossen unregelmässigen Poren. Die proximale Halfte der Arme tragt ebenfalls grobe Poren, die in Langsstreifen angeordnet sind. Die distale Hälfte der Arme besteht aus einem wuchtigen dreikantigen Stachel, der nach aussen nur langsam schmaler wird. Er setzt sich auch im Inneren des proximalen Anteils der Arme und im Inneren der Schale fort. Markschale gross, in geringem Abstand von der äusseren Schale gegelen. Die nach innen fortsetzenden Armstacheln treffen sich anscheinend im Schaleninneren.

Range: Upper Triassic (as far as known).

Occurrence (literature): Austria.
Occurrence (this study): West Timor, Indonesia.

Remarks: Pentaporobrachia differs from *Tetraporobrachia* by having five rather than four rays.

Pentaporobrachia sp. A
Pl. 10, fig. 4.
Cat. No. 3208/32.

Description: Test as with genus. Cortical shell large, subtetrahedrally shaped with polygonal pore frames with nodes at the pore frames vertices. Test has five stout arms, four arranged at the corners of the cortical shell with the fifth arm in between. Arms approximately one quarter the diameter of the test. Pore frames on the arms linearly arranged with longitudinal beams (as seen on well preserved specimens). Arms have short, tapering spine which are triradiate in axial section.

Dimensions: (microns):	Average of 4 specimens	max.	min.
Length of arms	146	156	138
Diameter of central shell	217	224	211

Material: 4 specimens

Range : Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: P. sp. A differs from *P. longispinosa* Kozur and Mostler, 1981 by having less well-developed pore frames and by having shorter terminal spines on the ray tips.

Genus ***TETRAPOROBRACHIA*** Kozur and Mostler, 1979.

Type species: Tetraporobrachia haeckeli Kozur and Mostler, 1979.

Description: Tetrahedrally shaped cortical shell with four symmetrically to asymmetrically arranged arms with linearly arranged pore frames. Arms terminate in triradiate spines.

Range: Upper Triassic.

Occurrence (literature): Austria, Queen Charlotte Islands, British Columbia.
Occurrence (this study): West Timor, Indonesia.

Remarks: Carter, 1993 noted that the external appearance of *Tetraporobrachia* is similar to *Hagiastrum*, however, triradiate beams extend the length of the arms.

Tetraporobrachia composita Carter, 1993.
Pl. 10, fig. 7.
Cat. No. 3208/33.

*1993 *Tetraporobrachia composita* Carter in Carter, p. 90, Pl. 12, figs. 7, 11.

Original description: (of Carter, 1993 p. 90) Test as with genus. Cortical shell large, tetrahedrally shaped, composed of regular, deep-walled, polygonal pore frames having small nodes at vertices of bars. Test has four, slender, symmetrically to assymetrically arranged arms, one arm extending from each corner of the cortical shell. Length of arms usually one-half to three-quarters diameter of shell; arms circular in cross section. Pore frames of arm linearly arranged, composed of longitudinal beams and horizontal cross bars that together form square pore frames; large rounded nodes situated at vertices of pore frames. Inner sphere connected to cortical shell by slender internal beams that extend the length of the arms and become fairly massive triradiate spines as they emerge beyond the arm tips. Length of spines approximately equal to length of arms; spines composed of wide rounded ridge and narrow, deep grooves.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of arms	204	209	199
Diameter of central shell	157	168	153

Material: 8 specimens

Range: Upper Triassic (upper Norian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 228).

Remarks: T. composita differs from *T. haeckeli* by having a larger, more tetrahedral-shaped cortical shell that is composed of well defined pore frames. *T. composita* differs from *T. asymmetrica* Kozur and Mostler, 1981 by having more well-developed longitudinal beams on the arms. *T. composita* as found during this study possibly range into the Rhaetian.

Tetraporobrachia longispinosa n. sp.
Pl. 10, fig. 9.
Cat. No. 3208/34 = Holotype fig. 9.

Diagnosis: This species of *Tetraporobrachia* is distinguished by irregular pore frames and extremely long rays.

Description: Test as with genus. Cortical shell small, tetrahedrally shaped composed of irregular, polygonal, pore frames with nodes at the pore frame vertices. Test has four slim, long asymmetrically arranged arms, with one arm extending from each corner of the cortical shell. Arms circular in axial section, forming more than three-quarters of the diameter of the shell. Spines on ray tips very long, almost as long as rays and comprise of three lamellae with deep groves and wide blades.

Dimensions (microns):	Average of 8 specimens	max.	min.	Holotype
Length of arms	382	391	379	391
Diameter of central shell	149	155	145	152
Length of spines on ray tip	177	182	175	175

Material: 11 specimens

Range: Upper Triassic (upper Norian-Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Etymology: longispinosa refers to the length of the rays which distinguish this species.

Type locality: River Meto sections, Soe, West Timor, Indonesia (see Chapter 4 log sections)

Remarks: This species differs from other species of *Tetraporobrachia* by having a combination of irregular pore frames and extremely long terminal spines.

?***Tetraporobrachia*** sp. A
Pl. 14, figs. 1, 2.
Cat. No. 3074/24.

Description: Cortical shell tetrahedral, composed of layers of irregularly arranged latticed meshwork. Arms arranged symmetrically in tetrahedral position. Arms composed of four stout longitudinal beams and cross bars. These enclose four rows of circular pores. Arms terminate in a central spine and smaller spines at the tips of the longitudinal bars.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of arms	129	138	125
Diameter of central shell	114	118	112

Material: 5 specimens

Range: Upper Triassic (lower Norian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: This form is tentatively placed in genus *Tetraporobrachia* because the internal structure is not known and therefore may possibly be assigned to *Pseudohagiastrium.*

Family **PARATRIASSOASTRIDAE** Kozur and Mostler, 1981.

Type genus: Paratriassoastrum Kozur and Mostler, 1981.

Original description: (for Family and Genus of Kozur and Mostler, 1981 p. 63) Spongiose bis unregelmassig gegitterte Radiolarien, deren Poren auf den Armen in Langsrichtung gestreckt sind, aber keine deutlichen Langsreihen bilden. Drei Arme liegen in einer Ebene wie bei *Paronaella* Pessagno, 1971 emend. Baumgartner, 1980. Ein vierter Arm liegt etwasenkrecht dazu oder weicht nur wenig von der Senkrechten ab. Auch das Innere der Arme und das Zentrum sind von lockerem spongiosem Material erf llt. Keine kugelige Markchale ausgebildet.

Range: Late Triassic (as far as known).

Occurrence (literature): Austria, Slovakia.

Occurrence (this study): W. Timor, Indonesia.

Included genera: Paratriassoastrum Kozur and Mostler, 1981.

Remarks: Paratriassoastrum is the only genus within the Family Paratriassoastridae Kozur and Mostler, 1981. Carter, 1993 remarked that this family and the Patulibracchiidae Pessagno, 1977 emend. Baumgartner, 1980 could be separated on the basis of internal structure (completely irregular in the Paratriassoastridae and layered in Patulibrachiidae).

Genus ***PARATRIASSOASTRUM*** Kozur and Mostler, 1981.

Type species: Paratriassoastrum austriacum Kozur and Mostler, 1981.

Original description: (for Family and Genus of Kozur and Mostler, 1981 p. 63) Spongiose bis unregelmässig gegitterte Radiolarien, deren Poren auf den Armen in Längsrichtung gestreckt sind, aber keine deutlichen Längsreihen bilden. Drei Arme liegen in einer Ebene wie bei *Paronaella* Pessagno, 1971 emend. Baumgartner, 1980. Ein vierter Arm liegt etwasenkrecht dazu oder weicht nur wenig von der Senkrechten ab. Auch das Innere der Arme und das Zentrum sind von lockerem spongiösem Material erfüllt. Keine kugelige Markchale ausgebildet.

Range: Upper Triassic.

Occurrence (literature): Austria, Queen Charlotte Islands, British Columbia.
Occurrence (this study): West Timor, Indonesia.

Remarks: Carter, 1993 noted that this genus was commonly occurring in Rhaetian samples from the Queen Charlotte Islands, British Columbia. *Paratriassoastrum* was only found in samples of Rhaetian age during this study.

***Paratriassoastrum*?** sp. A
Pl. 10, fig. 8, Pl. 13, fig. 10.
Cat. No. 3208/29, 3020/2.

Description: Test as with genus. Central shell small and subtetrahedral in shape. Rays very long, tapering with slight inflations at the ray tips and circular in axial section. Ray tips with central spine surrounded by a further three spines forming a crown. Meshwork poorly-developed especially on central shell.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of arms	470	483	462
Diameter of central shell	145	148	142

Material: 4 specimens

Range: Upper Triassic (upper Norian-Rhaetian).
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: Parartriassoastrum? sp. A is generally poorly preserved but differs from other species of *Paratriassoastrum* by having very long rays.

Family **PATULIBRACCHIIDAE** Pessagno, 1971
emend. Baumgartner, 1980.

Type genus: Patulibracchium Pessagno, 1971.

Description (Emended version of Baumgartner, 1980 p. 297): Spongodiscacea with two to five rays composed of uniform spongy meshwork. Meshwork of central area irregular or with faint radial bars, in rays arranged in layers parallel to equatorial plane of the test. Individual layers composed of linearly arranged meshes. External pore frames sometimes composed of external beams and bars, sometimes more irregular spongy with weak linearity. Bracchiopyle may be developed.

Range: Late Palaeozoic to Upper Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Paronaella Pessagno, 1971 emend. De Wever, 1982 *Bistarkum* Yeh, 1987 *Crucella* Pessagno, 1971 emend. Baumgartner, 1980 *Triassocrucella* Kozur, 1984.

Remarks: The Patulibracchiidae differ from the Hagiastridae by lacking the differentiated concentric shells and longitudinal canals (Textfig. A.1.7). This family also differs from the Euchitoniidae Haeckel, 1887 and Spongobrachiidae Haeckel, 1882 emend. Kozur and Mostler, 1978 by the total absence of concentric structure in the central area and by the presence of layered linearly arranged meshwork, which is not always evident externally.

Subfamily **PATULIBRACCHIINAE** Pessagno, 1971 **emend.** Baumgartner, 1980.

Type genus: Patulibracchiinae Pessagno, 1971.

Description: (of Baumgartner, 1980 p. 300) Two to four (or five) rayed patulibracchiids lacking prominent lateral external beams. Surface of rays with linear, sublinear or irregular arrangement of pores and nodes. Cross section of rays circular, elliptical or rounded rectangular. Inner structure as with family.

Range: Late Palaeozoic to Upper Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Paronaella Pessagno, 1971 emend. De Wever, 1982 *Crucella* Pessagno, 1971 emend. Baumgartner, 1980.

Remarks: The Patulibracchiinae differ from the Amphibracchiinae by the presence of prominent lateral beams forming a rectangular cross section of rays.

Genus ***PARONAELLA*** Pessagno, 1971 **emend.** De Wever, 1982.

*1971 *Paronaella* Pessagno, p. 46.
1971 *Patulibracchium* Pessagno, p. 26.
1978 *Pessagnobracchia* Kozur and Mostler, p. 142.
1980 *Paronaella* pessagno, **emend**. Baumgartner, p. 300.
1980 *Patulibracchium* Pessagno, Baumgartner, p. 308.
1981 *Paronaella* Pessagno, **emend**. De Wever, p. 33.

Type species: Paronaella salonoensis Pessagno, 1971.

Description: (emended version of De Wever, 1982) Patulibracchiinae with three arms, and with or without a bracchiopyle.

Range: Late Palaeozoic? to Upper Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Baumgartner (1980) included forms with bulbous or expanded ray tips within this genus, whereas in the original diagnosis of Pessagno he did not. De Wever (1982) noted that the definition of this genus had evolved from that of Pessagno (1971) based entirely on external features to Baumgartner (1980) when it was recognised that the internal structures were decisive for correct identification of this genus. The bracchiopyle, as reported by De Wever (1981) may or may not be present in this genus, thus its significance as a diagnositic feature is reduced.

Paronaella leebyi n. sp.
Pl. 8 figs. 2, 3, 4.
Cat. Nos. 3208/25 = Holotype fig. 2, Paratypes =3208/24, 3208/26, figs. 3, 4.

Diagnosis: This species of *Paronaella* is distinguished by irregular spongy meshwork and medially expanded rays.

Description: Test completely spongy and when well-preserved having slightly raised central areas. Rays moderately long, maintaining the same width along the entire length. Terminal spines can be variable on the same specimen, consisting of a tapering central spine with tapering spines on either side. Rays circular in axial section. Mesh-work fine and irregular, maybe slightly coarser on the raised section. Nodes small and varying slightly in size.

Dimensions (microns):	Average of 8 specimens	max.	min.	Holotype
Length of arms	229	242	217	238
Width of arms (excluding tip)	74	81	68	73

Material: 14 specimens

Range: Upper Triassic (upper Norian-Rhaetian).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 220, 224, 213).

Etymology: This species is named in honour of Leeby Littlebury for her work in teaching.

Type locality: River Meto sections, West Timor, Sample 220, 224 (see Chapter 4 log sections)

Remarks: Paronaella leebyi n. sp. appears to closely resemble *Paronaella? beatricia* Carter, 1993 the difference being that the form described herein does not have medially expanded ray tips. The spines described on *P. beatricia* also appear to differ slightly from *P. pessagnoi.* This species only occurs with characteristic forms (Sample 220, 224), which overall, is similar to the Rhaetian assemblages described by Carter, 1993.

Paronaella sp. aff. ***P. bifida*** Carter, 1993.
Pl. 8, fig. 1.
Cat. No. 3208/27.

*1993 *Paronaella bifida* Carter in Carter, p. 81, Pl. 10, figs. 2, 3.

Original description: (of Carter, 1993 p. 81)Stout form composed of multiple layers of pore frames having a small central area and short rays that distally bifurcate into two large lobes. Ray tips (measured perpendicular to axis of spine) approximately equal in width to axial length of rays. Meshwork, of central area and rays, spongy throughout. Pore frames generally uniform in size but sometimes smaller at lobe tips. Pore frames predominantly tetragonal and triangular with low rounded nodes at vertices. Ray tips usually eroded but on rare specimens short spines, one per lobe, have been observed.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of arms	194	203	187
Width of arms (excluding tip)	68	76	62

Material: 6 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: Carter, 1993 indicates that *P. bifida* develops into *P. ultrabifida* Carter, 1993 an elongate form with similar bifurcate ray tips. The form illustrated herein appears to be an intermediate between *P. bifida* and *P. ultrabifida.* This form occurs in a distinctive sample containing many of the forms reported by Carter, 1993 from the Rhaetian of the Queen Charlotte Islands.

Paronaella sp. A
Pl. 8 figs. 5, 8, 12, 13.
Cat. Nos. 3045/8, 3045/9.

Description: Test moderate is size with broad, short, equally sized rays which are expanded at the ray tips. Pore frames regularly arranged (sublinearly), uniform in size with heavy nodes at the pore frame vertices. Rays are subrectangular in axial section.

Dimensions (microns):	Average of 10 specimens	max.	min.
Length of arms	127	132	122
Width of arms (excluding tip)	60	63	58

Material: 14 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 242, 241, 216-217-218).

Remarks: P. sp. A appears to be similar to *P. gemmata* De Wever, 1981 (p. 33, Pl. 4, figs. 3-7) and *P.* sp. B of Carter *et al.*, 1988 p. 42, Pl. 11, fig. 6. The nodes at the pore frame vertices are heavily-developed in well-preserved examples. Less well-preserved forms are common and are identified by the shape and length of their rays and size of the ray tips.

Paronaella sp. B
Pl. 10, fig. 3.
Cat. No. 3251/6.

Description: Rays very short, equally sized and as broad as long. Ray tips slighty inflated with rounded terminations. Ray tips with a single, stout, tapering spine. Irregular meshwork with polygonal pore frames. Nodes at pore frame vertices large and globular.

Dimensions (microns):	Average of 10 specimens	max.	min.
Length of arms	112	119	109
Width of arms (excluding tip)	79	92	67

Material: 20 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246, 232).
Remarks: *Paronaella* sp. B differs from *P.* sp. A by having short rays with only slightly expanded ray tips.

Paronaella? sp. C
Not illustrated
Cat. No. 239/1.

Description: Rays moderately long, straight with parallel sides. Ray tips plane and straight. Meshwork difficult to discern, often poorly preserved.

Dimensions (microns):	Average of 10 specimens	max.	min.
Length of arms	105	111	90
Width of arms (excluding tip)	69	76	63

Material: 45 specimens

Range: Upper Triassic (upper Carnian) to Lower Jurassic (Pliensbachian-Toarcian) as far as known.

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 239, 233-234, 231, 229, 223, 209 (a), 209 (b), 205, 99+101).

Remarks: Paronaella sp. C differs from *P.* sp. A by having straight rays without bulbous ray tips

Genus ***CRUCELLA*** Pessagno, 1971 **emend.** Baumgartner, 1980.

Type species: Crucella messinae Pessagno, 1971.

Description: (emended version of Baumgartner, 1980 p. 306) Four-rayed Patulibracchiinae lacking a bracchiopyle, either with only a central spine or with central and lateral spines. With or without patagium .

Range: Late Palaeozoic-Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Forms recovered during this study only have one single spine at the end of the rays. The ray tips are generally slightly inflated. *Crucella* sp. A is not formally described herein, however, is illustrated (PL. 10, fig. 1, 2, Pl. 13, fig.1, 2, 12).

Family **HAGIASTRIDAE** Riedel, 1971 **emend.** Baumgartner, 1980

Type genus: Hagiastrum Haeckel, 1881.

Definition: (of Baumgartner, 1980 p. 287-288) Test composed of 2 to 4 (or 5) latticed rays extending from a small central area. Central area and rays differentiated into a cortical shell and concentriacally placed medullary shell. Rays of cortical shell composed of parallel, longitudinal beams connected by transverse bars forming longitudinal pore rows. External beams merge in central area to form a polygonal meshwork of bars. Nodes may be developed at vertices of beams and bars and on central area. Medullary shell connected by subsidiary beams to cortical shell. Medullary shell composed of a centrally placed discoidal latticed shell and medullary rays. Medullary rays composed of medullary beams and bars, inner space divided by 3 primary lamellae into 3 primary longitudinal canals symmetricallyarranged around primary beam. No bracchiopyle developed .

Range: Triassic to Lower Cretaceous

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: The Hagiastridae differ from the Patulibracchiidae by having a layered internal structure with internal medullary shells as opposed to a layered, linearly arranged internal meshwork.

Subfamily **HAGIASTRINAE** Riedel, 1971
emend. Baumgartner, 1980.

Type genus: Hagiastrum Haeckel, 1881 emend. Baumgartner, 1980.

Definition: (of Baumgartner, 1980 p. 288) Test as with family, composed of 2 to 4 rays extending from a central area which is simply formed by the convergence of the rays. Cortical rays composed of numerous (8-12) longitudinal external beams, connected by bars regularly in transvers rows forming single rows of circular, rectangular or parallelogram-shaped pores between beams. Cross section of ray circular or elliptical. Central area of cortical shell usually with smaller, more irregular pore frames, nodes may be developed.

Medullary shell centrally placed, about one-third the diameter of cortical shell, leaving a cylindrical cortical space around it. Medullary shell connected by numerous radially arranged beams to cortical shell. Medullary shell as with family, rays circular in cross section, composed of several medullry beams comprising 3 (sometimes up to six) primary canals. Central area of medullary shell with internal vertical beamlets.

Range: Triassic?-Lower Jurassic to Lower Cretaceous

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Didactylum Baumgartner, 1980 *Homeoparonaella* Baumgartner, 1980

Hagiastrum Haeckel, 1881.

Remarks: The Hagiatrinae differ from other subfamilies of hagiastrids by: 1) the presence of numerous external beams with single pore rows between them, 2) by the circular cross section of the rays; and 3) by the cylindrical cortical space around the medullary shell (Baumgartner, 1980 p. 288).

Genus *HOMEOPARONAELLA* Baumgartner, 1980.

Type species: Homeoparonaella elegans Pessagno, 1977a.

Original decription: (of Baumgartner, 1980 p. 288) Test as with subfamily, composed of 3 rays with equal to subequal interradial angles lacking a bracchiopyle and a patagium. Cortical rays composed of numerous longitudinal external beams connected by short bars in ttransverse rows forming small pore frames. Nodes well-developed. Ray tips bulbous with or without central spines.

Medullary shell composed of centrally placed medullary rays merging in central area. Medullary rays composed of 3 (sometimes 5) primary canals arranged around primary beams. Medullary shell connected to numerous radially arranged subsidiary beams to cortical shell.
Range: Upper Triassic to Lower Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Homeoparonaella is distinguished from other genera by having three rays with numerous external beams.

Homeoparonaella norica (Kozur and Mock, 1981)
Pl. 8, figs. 6, 7, 9, 10, 11.
Cat. Nos. 3045/6, 3045/13, 3045/11.

*1981 *Paronaella norica* Kozur and Mock in Kozur and Mostler, Pl. 46, fig. 2.
1994 *Homeoparonaella norica* Kozur and Mock, herein.

Original description: (of Kozur and Mostler, 1981 p. 61) Arme schlank, gleich breit, distal keulenformig verbreitert. Poren in parallelen Reihen angeordnet. Zwischen den Porenreihen sind die Gitterbalken zu schwachen Langsrippen verstarkt.

Dimensions (microns):	Average of 20 specimens	max.	min.
Length of arms	208	213	198
Width of arms (excluding tip)	46	47	44

Material: 48 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Alpine Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 246, 224, 223).

Remarks: Homeoparonaella norica differs from other species of *Homeoparonaella* by having regular rows of pore frames (sometimes exhibiting torsion) and bulbous ray tips. The internal canal structure of this species distinguishes it from the genus *Paronaella*.

Genus ***TRIASSOCRUCELLA*** Kozur, 1984.

Type species: Hagiastrum baloghi Kozur and Mostler, 1978.

Description: (see Kozur (1984)).

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe, North America.
Occurrence (this study): West Timor, Indonesia.

Remarks: These forms tend to have bulbous tips with central and lateral spines making them different from the genus *Crucella* Pessagno, 1971.

Triassocrucella sp. A
Pl. 10, fig. 5.
Cat. No. 3073/25.

Description: Test cruciform with moderately long rays of equal width throughout. Ray tips blunt with several short spines (in well-preserved specimens). Rays circular to subrectangular in axial section. Pore frames regular in size and shape.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of arms	188	192	184
Width of arms	54	58	52

Material: 5 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: T. sp. A is similar to *T.* sp. A Carter, 1993, however, this form has more coarse pore frames.

Family **FERRESIIDAE** Carter, 1993.

Type genus: Ferresium Blome, 1984.

Original description: (of Carter, 1993 p. 67-68) Test spherical, elliptical, triangular or three armed in oultine with three, coplanar primary spines. Upper and lower surfaces of test planiform to convex. Test composed of multiple layers of more or less regular, concentrically arranged meshwork. The outer shell, considered cortical, has thickened latticed meshwork composed of polygonal pore frames (mostly triangular) usually with prominent nodes at pore frame vertices; nodes interconnected by thin bars. Inner structure of test comprised of spongy meshwork that generally thickens centrifugally. Primary spines solid, bladed, equal to subequal in length, symmetrically to asymmetrically arranged, and usually twisted.

Range: Uppe Triassic (upper Norian and Rhaetian).

Occurrence (literature): Western North America, Oman, Russia, Japan, Philippines, New Zealand.
Occurrence (this study): West Timor, Indonesia.

Remarks: The Ferresiidae differ from the Pseudoaulophacidae by having less regular meshwork and by having twisted spines (usually).

Genus ***FERRESIUM*** Blome, 1984 **emend.** Carter, 1993.

Type species: Ferresium laseekense Blome 1984.

Emended definition: (of Carter, 1993 p. 68) Test ovate, spherical to triangular in outline, composed of a thickened cortical shell and inner spongy meshwork.

Range: Upper Triassic (upper Norian and Rhaetian).

Occurrence (literature): Western North America, New Zealand, Japan, Philippines and Oman.
Occurrence (this study): West Timor, Indonesia.

Remarks: See Carter (1993) for detailed discussion of inner structure of test. Carter (1993) states that in Norian strata containing radiolarians of the *Betraccium deweveri* Zone, the cortical shell of *Ferresium* is always circular, subcircular or elliptical in outline, while in younger strata, forms tend to be subtriangular to strongly triangular.

Ferresium loganense Blome, 1984.
Pl. 15, fig. 2.
Cat. No. 3073/28.

*1984 *Ferresium loganense* Blome in Blome, p. 43-44, Pl. 8, figs. 2, 7, 9, 15.

Description: (of Blome, 1984 p. 43-44) Test as with genus. Cortical shell inflated, spherical; top and bottom surfaces convex, sides slightly convex. Meshwork of cortical shell consisting of three layers of polygonal pore frames; outer layer exhibiting small, triangular to tetragonal pore frames with large, polygonal to subcircular nodes, nodes high in relief. Primary spines symmetrically arranged, massive, short; triradiate in axial section; longitudinally comprised of three wide grooves four to five times as wide as ridges; ridges and grooves displaying strong torsion.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	155	159	151
Length of arms	117	122	110
Width of arms	34	38	31

Material: 8 specimens

Range: Upper Triassic (upper Norian).

Occurrence (literature): Queen Charlotte Islands, British Columbia, New Zealand.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246, 232).

Remarks: F. loganense differs from *F. contortum* Blome, 1984 by having a less inflated cortical shell, larger polygonal pore frames with less closely spaced nodes at the pore frame vertices.

Ferresium sp. A
Pl. 15, fig. 5.
Cat. No. 3747/17.

Description: Test subtriangular in outline. Spines moderately long and strongly twisted. Meshwork is a mixture of triangular and polygonal pore frames.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	130	133	127
Length of arms	97	110	89
Width of arms	28	31	24

Material: 8 specimens

Range: Upper Triassic (Carnian/Norian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 216-7-8, 231, 232).

Remarks: This species differs from other recovered during this study by having finer meshwork. *F.* sp. A is similar to *F. teekwoonense* Carter, 1993, however, differs by having broader primary spines.

Genus ***ZHAMOJDASPHAERA*** Kozur and Mostler, 1979.

Type species: Zhamojdasphaera latispinosa Kozur and Mostler, 1979.

Original description: (of Kozur and Mostler, 1979 p. 66-67) Subspharische in der Aufsichtim umriss subtriangulare schale mit 3 sehr breiten, sehr flachen, propellerartig spiralig gedrehten Haupstacheln, die etwa so lang wie oder etwas langer als der ussere schalendurchmeiser sind. Innere schalernmerkmale nicht genau bekannt, schale hohle.

Range: Upper Triassic as far as known.

Occurrence (literature): Europe.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs other spumellarians by having three arms in the form of a blade or paddle which exhibits torsion.

Zhamojdasphaera*? *latispinosa Kozur and Mostler, 1979.
Pl. 23, figs. 2, 6.
Cat. No. 3074/6.

*1979 *Zhamojdasphaera latispinosa* Kozur and Mostler in Kozur and Mostler, p. 67, Pl. 7, figs. 7-9, Pl. 12, fig. 5.

Original description: (of Kozur and Mostler, 1979 p. 67) Subspharische in der Aufsichtim umriss subtriangulare schale mit 3 sehr breiten, sehr flachen, propellerartig spiralig gedrehten Haupstacheln, die etwa so lang wie oder etwas langer als der ussere schalendurchmeiser sind. Innere schalernmerkmale nicht genau bekannt, schale hohle.

Dimensions (microns):	Average of 5 specimens	max.	min.
Diameter of cortical shell	124	126	122
Length of arms	129	135	127

Material: 5 specimens

Range: Upper Triassic (Norian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: This species is similar to forms of *Bipedis* descibed herein, however, *Z. latispinosa* is a spumellarian with a subspherical cortical shell.

Genus ***ASTROCENTRUS*** Kozur and Mostler, 1979.

Type species: Astrocentrus pulcheri Kozur and Mostler, 1979.

Original description: (of Kozur and Mostler, 1979 p. 72) Kugelige feinporige Gitterschale mit 10-18 kraftigen Hauptstacheln. Diese sind basal stets breit, dreikantig und laufen spitz aus oder enden in einer nadelf rmigen verl ngerung Innere stacheln nadelf rmig, im Zentrum zusammenlaufend markschale klein.
Range: Upper Triassic as far as known.

Occurrence (literature): Europe.
Occurrence (this study): West Timor, Indonesia.

Remarks: This species differs from others by having discrete spines which are triradiate in axial section.

Astrocentrus sp. aff. ***A. pulcheri*** Kozur and Mostler, 1979.
Pl. 14, figs. 7, 8, 9.
Cat. Nos. 3073/4, 3054/28, 3100/12.

aff.*1979 *Astrocentrus pulcheri* Kozur and Mostler in Kozur and Mostler, p. 72, Pl. 1, figs. 2, 3, Pl. 2 figs. 1, 3.

Original description: (of Kozur and Mostler, 1979 p. 72) Die feinporige gegitterte a ssere kugelschale erscheint dirch Rekristallisation haufig spongios-dicht. Trotz der hohen individuenzahl wurden nur Formen mit 14 Haupstacheln nachgeweissen. Sie sind kraftig, basal stets breit und dreikantig, wobei sie sich nach aussen allmahlich verschmälern, oder sie sind im distalen Teil nadelförmig. Die markschale ist klein, gegittert. Die nadelförmigen inneren stacheln setzen sich im Inneren der Markschale fort und treffen sich in deren Zentrum.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of spines	71	170	67
Diameter of central shell	176	187	169

Material: 14 specimens

Range: Upper Triassic (Carnian-Rhaetian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 246, 220).

Remarks: This species differs from other by the combination of small, irregular pore frames and discrete triradiate spines.

Genus *SPONGOSERRULA* Dumitrica, 1982.

Type species: Spongoserrula rarauana Dumitrica, 1982.

Original description: (of Dumitrica, 1982) Spine asymmetrical, curved and lamellar, with a variable number of teeth on the external side.

Range: Middle to Upper Triassic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Dumitrica (1982) noted that this genus differs from *Falcispongus* Dumitrica, 1982 by having a completely flattened spine and presence of teeth on the external margin.

Spongoserrula? sp. A
Pl. 16, figs. 7, 10.
Cat. No. 3074/28.

Description: Test spherical, spongy with two broad, antler-like primary spines. Primary spines expand rapidly to form a subtriagular, rounded blade with curved spines at the corners (two spines at one corner the others with one spines only).

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of arms	229	231	228
Diameter of central shell	138	143	135

Material: 4 specimens

Range: Upper Triassic (Norian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246, 232).

Remarks: Spongoserrula? sp. A differs from other species by having very broad, antler-like spines.

Family **XIPHOSTYLIDAE** Haeckel, 1881
emend. Pessagno *et al.*, 1989.

Type genus: Xiphostylus Haeckel, 1881.

Description: (of Pessagno *et al.*, 1989 p. 202) Test with cortical shellonly, lacking primary radial beams or internal spicules. Cortical shell variable in shape with symmetrical polygonal pore frames. Wall of cortical shell consisting og two fused layers of latticed meshwork: (1) a thin inner layer with flattened pore frames (e.g. *Triactoma* Rust, *Tripocyclia* Haeckel, *Xiphostylus* Haeckel; Pl. 1, figs. 2, 8). Juncture between inner and outer latticed layers referred to as the primary lamella. Cortical shell lacking secondary spines, or with two or more symmetrically arranged secondary spines, or with three asymmetrically arranged secondary spines. Secondary spines predominantly triradiate in axial section with three longitudinal grooves alternating with three longitudinal ridges. Secondary spines with or without cortical buttresses.

Range: Mesozoic (Triassic to Cretaceous).

Occurrence (literature): Worldwide (Tethyan Realm and southern Boreal Realm).
Occurrence (this study): West Timor, Indonesia.

Remarks: The Xiphostylidae differ from the Pantanelliidae by lacking a medullary shell, primary spines, primary radial beams, and by possessing a cortical shell with two fused latticed layers.

Genus ***ARCHAEOCENOSPHAERA*** Pessagno *et al.*, 1989.

Type species: Archaeocenosphaera ruesti Pessagno *et al.*, 1989.

Original description: (of Pessagno *et al.*, 1989 p. 203) Cortical shell spherical, lacking spines, consisting of two fused latticed layers. Latticed layers comprise of symmetrical polygonal pore frames. Outer latticed layers often quite thick.

Range: Palaeozoic?; Triassic to Cretaceous (as far as known).

Occurrence (literature): Tethyan and Boreal Realms.
Occurrence (this study): West Timor, Indonesia.

Remarks: Archaeocenosphaera differs from *Cenosphaera* Ehrenberg by having a thick cortical shell with two fused latticed layers and by usually having symmetrical polygonal pore frames. *Archaeocenosphaera* differs from *Triactoma* by lacking three secondary spines.

Archaeocenosphaera? sp. A
Pl. 16, fig. 13.
Cat. No. 3747/19.

Description: Cortical shell spherical with symmetrical meshwork with several short, fine triradiate spines.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of test	365	378	359
Thickness of test walls	41	43	40
Length of spines	86	94	81

Material: 56 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 216-217-218, 232, 223, 220).

Remarks: This form is tentatively placed within the genus *Archaeocenosphaera* and differs from forms by being much larger (see Carter, 1993 Pl. 1).

Genus *NATRAGLIA* Pessagno, 1979.

Type species: Natraglia liminosa Pessagno, 1979.

Original description: (of Pessagno, 1979 p. 171-172) Test basically disc-shaped with radially arranged, opposed, paired spongy bracchia situated along same axis; each braccium terminating in a solid spine.

Range: Upper Triassic (as far as known).

Occurrence (literature): Western North America.
Occurrence (this study): West Timor, Indonesia.

Remarks: Natraglia differs from *Stylospongia* Haeckel (1862) by possessing spongy bracchia on the periphery of the spongy disc.

Natraglia sp. A
Pl. 16, fig. 6.
Cat. No. 3914/13.

Description: Spongy test, star-shaped with three pairs of opposed bracchia, each one of each pair situated in the same axis. Brachia short, triangular with rounded tips.

Dimensions (microns):	Average of 8 specimens	max.	min.
length of peripheral tips	221	138	98
Total diameter of test	451	458	443

Material: 18 specimens

Range: Upper Triassic.

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 041S).

Remarks: This species differs from others by having rounded triangular tips.

SPUMELLARIINA **Incertae sedis**

Genus ***PSEUDOHAGIASTRUM*** Pessagno, 1979

Type species: Pseudohagiastrum monstruosum Pessagno, 1979.

Original description: (of Pessagno, 1979 p. 165) Test with four rays at right angles, not in the same plane, and with small central area. Rays circular in axial section, having spongy meshwork consisting of irregular, more or less linearly arranged, polygonal pore frames. Ray tips with short, solid spines extending out from the sides.
Range: Upper Triassic (Norian).

Occurrence (literature): Oregon, California, Baja California, Alaska.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Pseudohagiastrum differs from *Hagiastrum* Haeckel, 1881 (emend. Pessagno 1971, 1977; emend. Baumgartner, 1980) by having rays which are circular in axial section, situated in different planes.

Pseudohagiastrum monstruosum Pessagno, 1979.
Pl. 10, fig. 6.
Cat. No. 3056/31.

*1979 *Pseudohagiastrum monstruosum* Pessagno in Pessagno *et al.*, p. 165, Pl. 6, figs. 1-2.

1993 *Pseudohagiastrum* sp. cf. *P. monstuosum* Pessagno; Carter, p. 88, Pl. 12, fig. 4.

Original description: (of Pessagno, 1979 p. 165) Test as with genus. Rays and central areas with irregular, predominantly tetragonal pore frames with circular to elliptical pores. Each ray terminating in a crown of four short spines.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of arms	87	91	84
Width of arms (excluding tip)	44	46	43

Material: 19 specimens

Range: Upper Triassic (middle to upper Norian).

Occurrence (literature): Baja California.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: P. monstuosum is distinguished from other species by having an irregular central area and rays terminating in a crown of four short spines.

Pseudohagiastrum longabrachiatum Carter, 1993.
Pl. 10, figs. 10, 11.
Cat. Nos. 3208/30, 3208/11.

*1993 *Pseudohagiastrum longabrachiatum* Carter in Carter, p. 88, Pl. 12, figs. 1, 8; Pl. 13, figs. 17, 18.

Original description: (of Carter, 1993 p. 88) Test as with genus, very large. Rays long (3 to 4 times diameter of central area), approximately equal in length, more or less inflated distally, and hollow, at least in inflated portion. Rays not in same plane but do not deviate strongly form it. Pore frames of rays and central area irregular in size and shape. Terminal spines on rays variable in size and number and the number of spines per ray may vary considerably on the same specimen. Most frequently several short, fine spines extend from tips of rays but occasionally there is only a central spine.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of arms	361	370	355
Width of arms (excluding tip)	71	74	69

Material: 5 specimens

Range: Upper Triassic (upper Norian/ Rhatian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 220).

Remarks: Differs slightly from *P. ? tasuense* Carter, 1993 by having totally irregular pore frames.

Pseudohagiastrum sp. aff. ***P. monstruosum*** Pessagno, 1979.
Pl. 15, fig. 4.
Cat. No. 3074/32.

aff.*1979 *Pseudohagiastrum monstruosum* Pessagno in Pessagno *et al.*, p. 165, Pl. 6, figs. 1-2.
aff.1993 *Pseudohagiastrum* sp. cf. *P. monstuosum* Pessagno; Carter, p. 88, Pl. 12, fig. 4.

Original description: (of Pessagno, 1979 p. 165) Test as with genus. Rays and central areas with irregular, predominantly tetragonal pore frames with circular to elliptical pores. Each ray terminating in a crown of four short spines.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of arms	92	98	82
Width of arms (excluding tip)	46	51	43

Material: 4 specimens

Range: Upper Triassic (middle to upper Norian).

Occurrence (literature): Baja California.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246).

Remarks: ***P.*** sp. aff. ***P. monstuosum*** is distinguished from other species by having an irregular central area and rays terminating in a crown of four short spines.

?***Pseudohagiastrum*** sp. A
Pl. 13, fig. 11.
Cat. No. 3251/6.

Description: Test as with genus. Rays and central area with irregular pore frames with circular to elliptical pores. Each ray terminating in a long spine with small spines at termination.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of arms	405	420	389
Width of arms (excluding tip)	61	63	59

Material: 4 specimens

Range: Upper Triassic (Carnian-Norian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 231).

Remarks: This species is similar to *Pseudohagiastrum* ? sp. A in Carter, 1993 Pl. 12, fig. 5, it differs by having a long distal spine and by having shorter rays (excluding ray spines).

Spumellaria gen. indet. and sp. indet. A
Pl. 16, figs. 2, 3, 4.
Cat. Nos. 3073/3, 3057/14, 3073/13.

Description: These forms consist of a subtriangular cortical shell with three equally-spaced arms. Cortical shell spongy, internal structure not known. Arms consist of a single blade which is rolled to form a partially enclosed arrangement with thickened ridges. Ridges exhibit a degree of torsion along with the whole arm structure. Arms terminate in a single tapering spine.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of spines	155	208	95
Diameter of central shell	127	135	120

Material: 20 specimens
Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246, 223, 232, 231).

Remarks: This genus differs from other by having three bladed primary spines which are rolled almost into a tube and exhibit torsion of the blades and the arms.

Spumellarian specimens marked LOST or NOT ILLUSTRATED

Betraccium sp A
Lost
Cat. No. 224/1

Description: Cortical shell spherical with large, predominantly hexagonal pore frames having well-developed nodes at pore frame vertices; nodes moderately high in relief. Primary spines relatively long, triradiate in axial section, comprising of three wide grooves alternating with three narrow ridges; grooves three to four times wider than ridges; ridges and grooves displaying moderate to strong torsion.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of cortical shell	91	99	84
Length of arms	112	119	107
Width of arms	39	44	33

Material: 8 specimens

Range: Upper Triassic (upper Norian-Rhaetian).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 224).

Remarks: This species differs from *B. deweveri* by exhibiting less torsion of the ridges and grooves of the primary spines, other specimens were not illustrated as they tended to be poorly preserved.

Pantanellium sp. aff. ***P. fosteri*** Pessagno and Blome, 1980
Not illustrated
Cat. No. Tr 90 036/1

aff.* 1980 *Pantanellium fosteri* Pessagno and Blome Pessagno and Blome, p. 242, Pl. 3, figs. 1, 8, 16.
1993 *Pantanellium* sp. aff. *P. fosteri* Pessagno and Blome; Carter, 1993, p. 64-65, Pl. 7, figs. 2, 3.

Original description: (of Pessagno and Blome, 1980 p. 242) Cortical shell spherical with large pentagonal and hexagonal pore frames (predominantly hexagonal) with well-developed nodes at pore frames vertices; nodes moderately high in relief. Pore frames thin along the Y, thick (4 times thicker) along Z. Five pore frames along AA and BB . Polar spines triradiate in axial section; longitudinally comprised of three broad grooves alternating with three broad ridges; grooves about same width as ridges; grooves extending to the top of both spines. Both polar spines short, of nearly equal length.

Dimensions (microns):	Average of 4 specimens	max.	min.
Diameter of cortical shell	83	89	77
Length of arm	97	111	94
Width of arms (at base)	36	38	34

Material: 4 specimens

Range: Upper Triassic (upper Norian and Rhaetian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample Tr 90 035s, Tr 90 036s).

Remarks: Pantanellium sp. aff. *P. fosteri* is very similar to *P.* sp. aff. *P. fosteri* illustrated by Carter, 1993 and differs from the original by having slightly longer primary spines.

Capnuchosphaera sp. aff. ***C. tortuosa*** Yeh, 1990
Lost
Cat. No. 223/2.

aff. *1990 *Capnuchosphaera tortuosa* Yeh in Yeh, Pl. 3, fig. 1, 2, 9.

Original description: (Yeh, 1990 p. 9) Cortical shell moderate in size, subcircular to subtriangular in outline with flattened areas around the base of each tumidaspina. Meshwork comprises of variably sized pores with polygonal pore frames. Nodes are present at the pore frame vertices. Tumidaspinae broad and heavy, spinal tunnels relatively short, circular in axial section, spinal tumour prominent showing a great deal of torsion of the lamellae; spinal shaft long, relatively thick and circular in axial section.

Dimensions (microns):	Average of 5 specimens	max.	min.
Diameter of cortical shell	135	139	128
Length of arms	156	168	147

Material: 5 specimens
Range: Upper Triassic (late Carnian-middle Norian).

Occurrence (literature): Philippines.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223).

Remarks: Capnuchosphaera sp. aff. *C. tortuosa* differs slightly from *C. tortuosa* Yeh, 1990 by having a larger more robust cortical shell, by showing more torsion in the tumoural elements and by not having a cortical shell obviously triangular in outline.

Vinassaspongus transitus Kozur and Mostler, 1981.
Not illustrated
Cat. No. 223/4.

* 1981 *Vinassaspongus transitus* Kozur and Mostler in Kozur and Mostler, p. 69-70, Pl. 64, fig 1.

Original description: (Kozur and Mostler, 1981 p. 69-70) Aussere Schale dickwandig, spharisch bis subspharisch, feinporig bis spongios mit der Tendenz, dass die spongios Ausbildung in eine zweischichtig-gegitterte Ausbildung mit feinporig innerer und grobporig aussere Schicht ubergeht. Die drei Arme weisen gedrehte Kanten auf und verbreitern sich nach aussen betrachtlich. Der breite, aussen abrupt abgestumpfte distale Teil ist breiter als der halbe Durchmesser der ausseren Schale. Zentral-distal ist ein langer runder Stachel aufgesetzt, der bei voller Erhaltung etwa so lang wie die Arme ist. Innenmerkmale wie fur die Gattung.

Dimensions (microns):	Average of 10 specimens	max.	min.
Length of spines	210	216	207
Diameter of central shell	128	134	121

Material: 88 specimens

Range: Upper Triassic (Norian, as far as known).

Occurrence (literature): Hungary, Austria, Italy, Slovakia.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 223, 228, 232).

Remarks: This species differs from species of *Sarla* by having a spongy cortical shell and wider ridges on the primary arms. This may be opportunistic as when it is present in samples it usually represents a large proportion of the total assemblage.

Paratriassoastrum sp. aff. ***P. omegaense*** Carter, 1993.
Lost
Cat. No. 3214/28.

aff.* 1993, *Paratriassoastrum omegaense* Carter in Carter, p. 78, Pl. 11, figs. 4, 7, 8, 14, 19.

Original description: (of Carter, 1993 p. 78) Test as with genus. Central shell small, subspherical to subtetrahedral. Rays of medium length, slightly expanded medially, circular in cross section. Tips of rays bear short spines; most often there is a single, short, porous central spine but sometimes there are multiple short, fine, solid spines. Meshwork of central shell and rays entirely spongy, coarse and irregularly arranged. On well-preserved specimens fine spinules extend randomly from surfaces of rays.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of arms	181	187	176
Diameter of central shell	82	85	80

Material: 5 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 224).

Remarks: P. sp. aff. *P. omegaense* Carter, 1993 differs from *P. cordevolicum* by having slightly longer rays. Carter, 1993 noted the usefulness of this species as a marker for the latest Rhaetian.

Paronaella*?* sp. C
Not illustrated
Cat. No. 239/1.

Description: Rays moderately long, straight with parallel sides. Ray tips plane and straight. Meshwork difficult to discern, often poorly preserved.

Dimensions (microns):	Average of 10 specimens	max.	min.
Length of arms	105	111	90
Width of arms (excluding tip)	69	76	63

Material: 45 specimens

Range: Upper Triassic (upper Carnian) to Lower Jurassic (Pliensbachian-Toarcian) as far as known.

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 239, 233-234, 231, 229, 223, 209 (a), 209 (b), 205, 99+101).

Remarks: Paronaella sp. C differs from *P.* sp. A by having straight rays without bulbous ray tips

Suborder **NASSELLARIINA** Ehrenberg, 1875.

Family **BULBOCYRTIDAE** Kozur and Mostler, 1981.

Type genus: Bulbocyrtium Kozur and Mostler, 1981

Original description: (of Kozur and Mostler, 1981 p. 106) Sehr grosser, ballonformig aufgeblahter Cephalis, der eine kraftige grob-netzformige Rippenskulptur tragt. Sehr kurzes Apicalhorn kann vorhanden sein. Thorax meist kleiner ais Cephalis, z. T. auch etwas grosser ald diesser. Letztes Segment (Abdomen oder postabdominales segment) trichterformig ertweitert, unperforiert oder mit grossen Poren. Cephalisches Spicularsystem mit Mb, A, D, V, L und I.

Range: Upper Triassic (as far as known).

Occurrence (literature): Oregon, Queen Charlotte Islands, British Columbia, European Tethys.
Occurrence (this study): W. Timor, Indonsesia.

Included genera: Bulbocyrtium Kozur and Mostler, 1981.

Remarks: This family differs from other groups of cyrtid radiolarians by having a large spherical cephalis with a network of ridges, and from *Squinobolella and Dreyercyrtium* by having post-abdominal chambers.

Genus ***BULBOCYRTIUM*** Kozur and Mostler, 1981.

Type species: Bulbocyrtium reticulatum Kozur and Mostler, 1981

Original description: (of Kozur and Mostler, 1981 p. 106) Tricyrtid oder tetracyrtid. Der sehr stark aufgeblahte ballonformige Cephalis ist stets grosser als der Thorax. Cephaliswand unperforiert und mit kraftiger Rippenskulptur, die ein weitmaschiges Netz bildet. Ein kleines rundes Apicalhorn kann vorhanden sein. Thorax, bei tetracyrtiden Formen auch Abdomen, sind feinporig und wesentlich kleiner als der Cephalis. Abdomen (bei tricyrtiden Formen) oder postabdominales Segment trichterformig erweitert, unperforiert.

Range: Upper Triassic (Carnian-Norian as far as known).

Occurrence: (literature): Oregon, Queen Charlotte Islands, British Columbia, European Tethys.
Occurrence: (this study): W. Timor, Indonesia.

Remarks: Bulbocyrtium differs from *Pessagnocyrtium* Kozur and Mostler, 1981 by having a larger cephalis relative to the thorax and abdomen.

Bulbocyrtium reticulatum Kozur and Mostler, 1981
Pl. 24, fig. 10, Pl. 25, fig. 6.
Cat. No. 3015/20, 3015/21.

*1981 *Bulbocyrtium reticulatum* Kozur and Mostler in Kozur and Mostler, Pl. 11, fig. 1.
aff.1989 *Bulbocyrtium* aff. *B. reticulatum* Kozur and Mostler; Carter, Pl. 1, fig. 1.

Original description: (of Kozur and Mostler, 1981 p. 106) Mit den Gattungsmerkmalen. Tetrtacyrtid. Die Rippen auf dem Cephalis bilden auf der unperforierten Wand ein ausseres Retikulum mit grossen, im distalen Teil sehr grossen Maschen. Kreuzungspunkte des Retikulums mit sehr kurzen Dornen. Der kleiporige Thorax ist wesentlich kleiner, gegen cephalis und Abdomen durch eine Einschnurung abgegrenzt. Abdomen ebenfallskleiner als Cephalis, feinporig durch Einschnurungen gegen die benachbarten Segmente abgegrenzt. Postabdominales Segment trichterformig erweittert, unperforiert.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of test	362	370	356
Diameter test (widest)	147	153	146
Diameter of distal skirt	218	221	212

Material: 8 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Western N. America, European Tethys.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: Bulbocyrtium reticulatum Kozur and Mostler, 1981 differs from other species of *Bulbocyrtium* by having a thorax, abdomen and postabdominal chambers that gradually increase in diameter.

Bulbocyrtium sp. A
Pl. 24, fig. 6.
Cat. No. 3074/12.

Description: Cephalis large, spherical. Pores on the cephalis small and irregular; pore frames irregular with nodes at the pore frame vertices. The constriction between the cephalis and the smaller thorax is imporate. Thorax smaller than the abdomen, imperforate. Abdomen slightly larger than the thorax, imperforate. Distally the test becomes smooth subcylindrical and terminates in a flared, turned-out lip which is almost twice the diameter than the cephalis.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of test	474	486	466
Diameter test (widest)	176	182	168
Diameter of thoracic skirt	345	352	341

Material: 15 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 232, 231, 223).

Remarks: Bulbocyrtium sp. A differs from other species of *Bulbocyrtium* by having a postabdominal chamber which rapidly inflates distally.

Family **CANOPTIDAE** Pessagno, 1979

Type genus: Canoptum Pessagno, 1979.

Original description: (of Pessagno *et al.*, 1979 p. 181-182) Test multicyrtoid, typically spindle-shaped when entire, conical when broken, including six or more postabdominal segments. Cephalis lacking horn on specimens thus far examined. Test wall consisting of an inner layer of polygonal pore frames and an outer layer of microgranular material lacking discrete pore frames (Pessagno, 1979 Pl. 4, figs. 10-16). Primary pores often penetrating outer layer along circumferencial ridges at joints between chambers.

Range: Upper Triassic (Carnian?-Norian) to Lower Jurassic (Toarcian).

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Canoptum Pessagno, 1979 *Pachus* Blome, 1984.

Remarks: Of particular importance in the definition of this family is the manner in which its test is built. Examination of the postabdominal segments indicates that the inner layer of polygonal pore frames is secreted first and is subsequently buried by an outer layer of accreted micrigranular silica. The fact that the outer layer is considerably thinner on the final postabdominal segments suggests that, each time a chamber is formed , microgranular silica is deposited in lamellae over the test in a manner which is somewhat analogous to that of the lamellar hyaline Foraminiferida.

The Canoptidae are not unique among the Nassellariina in forming a layered test wall. The Parvicingulidae Pessagno (1977) and the Xitidae Pessagno (1977) form two or three layered test walls. However, these families lack an outer layer comprising of microgranular silica.

Superficially, the Canoptidae resemble the Spongocapsulidae Pessagno (1977). The latter, however, possesses postabdominal segments with spongy test walls. *Dictyomitra arrecta* Hinde (1908), described from the Triassic of the East Indies (cherts with *Halobia*), appears to fall within this family group (Pessagno *et al.*, 1979).

Genus ***CANOPTUM*** Pessagno, 1979.

Type species: Canoptum poissoni Pessagno, 1979

Original description: (of Pessagno *et al.*, 1979 p. 182) Test spindle-shaped (often conical when broken) with dome-shaped cephalis lacking horn. Thorax and abdomen trapezoidal in outline. Post abdominal segments subtrapezoidal in outline, seperated from each other by a rather broad, slightly perforate, circumferential ridges at the joints;

pores on ridges cicular to elliptical in shape, not set in pore frames. Ridges of inner layer considerably narrower. Area between given ridges imperforate or sparsely perforate. Segments somewhat constricted between joints and circumferential ridges. Each postabdominal segment seperated by partitions with large, circular apertures.

Range: Upper Triassic (Carnian) to Middle Jurassic (lower Bajocian).

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Canoptum Pessagno, 1979 differs from *Spongocapsulum* Pessagno, 1977 in having a two-layered test wall lacking a spongy meshwork. *Canoptum* differs from *Parvicingula* Pessagno, 1977 in possessing a two-layered test with a microgranular outer layer lacking discrete pore frames, *Canoptum* differs from *Wrangellium* Pessagno and Whalen, 1982 by lacking large primary pores on its circumferential ridges and by having asymmetrical rows of pore frames in the constrictions between ridges.

Canoptum triassicum Yao, 1982.
PL. 26, figs. 2, 7, 12.
Cat. Nos. 3608/21, 3251/29, 3214/18.

1979 *Canoptum* sp. A Pessagno p. 184, Pl. 4, fig. 9.
*1982 *Canoptum triassicum* Yao, p. 60, Pl. 3, figs. 1-4.
1986 *Canop[tum triassicum* Yao; Yoshida, p. 11, Pl. 4, fig.11.

Original description: (of Yao, 1982 p. 60) Shell conical proximally , and subcylindrical distally, with 8-12 preserved segments. Cephalis dome-shaped without apical horn. Internal cephalic structure unknown. Cephalis and thorax poreless with smooth surface. Post-thoracic segments trapezoidal to subtrapezoidal in outline, seperated from each other by perforated well-developed circumferential ridges at the joints. Post-cephalic segments increases gradually in width and in height. Width of each segment approximately four times the height. Pores on ridges small, circular in shape, irregularly arranged. Area between ridges imperforate.

Dimensions (microns):	Average of 15 specimens	max.	min.
Length of test	286	310	254
Diameter test (widest)	123	157	83

Material: 122 specimens

Range: Upper Triassic (upper Carnian) to Middle Jurassic (lower Bajocian).

Occurrence (literature): Japan, Western North America.
Occurrence (this study): Noil Meto, W. Timor, Indonesia (Sample 231, 246, 241, 239, 233-234, 232, 223, 220, 216-217-218, 211).

Remarks: Canoptum triassicum differs from *Canoptum poissoni* Pessagno, 1979 in having a conical shell with well-developed circumferential ridges. This species is very similar to to *Canoptum* sp. A reported by Pessagno *et al.* (1979, p. 184, Pl. 4, fig. 9) from the Upper Triassic of San Hipolito, Baja California.

Canoptum ? sp. A
Pl. 26, fig. 1.
Cat. No. 3908/16.

Description: Conical proximal area with six preserved ridges; cephalis conical, poreless and smooth to slightly pointed; post thoracic segments consist of very narrow ridges seperated by wide, shallow constrictions between ridges; chambers increase in thickness and width distally, distal chamber decreases in width slightly. One row of circular pores observed just above the ridges of the distal chambers.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of test	254	264	248
Diameter test (widest)	98	109	93

Material: 10 specimens

Range: Upper Triassic (Carnian-Norian boundary).

Occurrence (this study): Noil Meto, W. Timor, Indonesia (Sample 223, 209 (a), 205).

Remarks: Canoptum sp. A differs from *C. triassicum* by having fewer ridges and wide, shallow constrictions between the ridges The ridges appear to be covered in small circular pores similar to *C. poissoni* Pessagno, 1979 differing in the shape of the circumferential ridges.

Genus *PACHUS* Blome, 1984.

Type species: Pachus firmus Blome, 1984.

Original description: (of Blome, 1984 p. 48) Test as for family. Test grossly conical, inflated, with a dome-shaped, imperforate cephalis, with horn. Thorax and abdomen trapezoidal in outline. Post-abdominal chambers trapezoidal to rectangular in outline; earlier post-abdominal chambers generally trapezoidal in outline, final postabdominal chambers rectangular in outline. All chambers separated by broad, highly nodose circumferential ridges; ridges with one or two rows of variably sized nodes,, nodes generally high in relief. Area between two given circumferential ridges perforate to imperforate, pores aligned in rows flanking ridges; pores circular to elliptical in outline, not set in pore frames; pores may be buried by an outer layer of accreted microgranular silica. Chambers constricted between joints.

Range: Upper Triassic (Carnian to middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): West Timor, Indonesia.

Remarks: Pachus differs from *Canoptum* by possessing a horn and from *Relanus* by possessing broad, nodose circumferential ridges.

Pachus sp. aff. ***P. longinquus*** Blome, 1984.
Pl. 26, figs. 5, 6.
Cat. Nos. 3026/28, 3056/7.

aff.*1984 *Pachus longinquus* Blome in Blome, p. 49-50, Pl. 12, figs. 6, 11, 13, 14, Pl. 17, fig. 9.

Original description: (of Blome, 1984 p. 49-50) Test as for genus. Cephalis with wel-developed horn. Five to six post-abdominal chambers, increasing gradually in width and more rapidly in height as added, the exception being the great increase in width between the second and third post-abdominal chambers; width of any given chamber approximately twice the height. Circumferential ridges of outer layer with one row of large, subspherical nodes on thorax, abdomen and early post-abdominal chambers; two rows of nodes on final post-abdominal chambers; nodes high in relief. Area between any two given ridges perforate, pores circular to subcircular in outline. Chambers slightly constricted between joints.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of test	265	274	253
Diameter of test (widest)	108	112	96

Material: 10 specimens

Range: Upper Triassic (Carnian to middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 223).

Remarks: This form differs slightly from the holotype of Blome (1984) by not having two distinct rows of pores on the final post-abdominal chambers.

Genus ***KARNOSPONGELLA*** Kozur and Mostler, 1981.

Type species: Karnospongella bispinosa Kozur and Mostler, 1981

Original description: (of Kozur and Mostler, 1981 p. 42) Die spongiose, langgestreckt ellipsoidale Schale besteht aus ca. 5 annahernd konzentrisch angeordneten schichten. An einem Pol zweigen zwei wuchtige Hauptstacheln ab, die einen Winkel von uber 90 einschleissen. Ihre Kanten sind Kraftig gedreht. Der andere Pol besitzt eine pylomahnliche Strucktur.

Range: Upper Triassic (as far as known).

Occurrence (literature): Austria.
Occurrence (this study): W. Timor, Indonesia.

Remarks: The main features that set this genus aside from others is the ellipsoidal, spongy cephallis, thorax and abdomen. Two apical horns set at 90 apart from each other, consisting of ridges and grooves exhibiting extreme torsion.

Karnospongella bispinosa Kozur and Mostler, 1981
Pl. 23, figs. 4, 5.
Cat. No. 3074/10.

*1981 *Karnospongella bispinosa* Kozur and Mostler in Kozur and Mostler, Pl. 50. figs. 1, 2.

Original description: (of Kozur and Mostler, 1981 p. 42) Spongiose Schale mit ca. 5 undeutlich konzentrischen Schichten, langgestreckt-ellipsoidal. Ein Pol ist abgeplattet und weist eine pylomahnliche Strucktur auf, die durch eine leichte Einsenkung und starke Auflockerung des Gewebes gekennzeichnet ist. Am anderen Pol zweigen zwei sehr wuchtige Hauptstacheln ab, die einen Winkel von mehr als 90 einschliessen und deren Kanten stark gedreht sind.

Dimensions (microns):	Average of 7 specimens	max.	min.
Length apical spines	88	97	82
Length of test	212	227	189

Material: 7 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Austria.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 231, 232).

Remarks: This species is distinguished by the two apical horns which exhibit extreme torsion.

Family **PALAEOSCENIDIIDAE** Riedel, 1967 **emend.** Holdsworth, 1977.

Subfamily **PENTACTINOCARPINAE** Dumitrica, 1978.

Type genus: Pentactinocarpus Dumitrica, 1978

Original description: (of Dumitrica, 1978) Latticed or possibly (?) spicular radiolarians having as a basis a pentactine spicule with two main parts: an apical spine and four bar or point-centred basal spines with a verticile of two, possibly (?) four spinules at some distance from spicule centre; when skeleton has two or more shells the pentactine structure occupies the innermost part.

Range: Upper Triassic (Ladinian-Carnian as far as known).

Occurrence (literature): Worldwide.
Occurrence (this study): W. Timor, Indonesia.

Included genera: Pentactinocarpus Dumitrica, 1978.

Remarks: Dumitrica (1978) in describing this subfamily points out that, generally the radiolarians within this family form a very homogeneous group. They have the spicule in common, which differs from the *Palaeoscenidium* Deflandre by the number of apical spines, absence of flat lamellae, connecting proximally the basal spines and the presence of the verticil of two or possibly four spinules. The number of apical spines is probably not an important distinctive character, as a tendency toward reduction may be observed. A few specimens of Triassic Pentactinocarpinae have a shorter additional apical spine.

The absence of proximally flat lamellae connecting the basal spines does not seem to be a particularly important character between the Palaeozoic and Triassic palaeoscenidiids. It is probably only a generic or even specific character.

In conclusion Dumitrica distinguishes characteristics of the Pentactinocarpinae from the *Palaeoscenidium* by the presence of of a single apical spine, of a verticil of spinules within the proximal portion of the basal spines, and quite probably a latticed shell.

Kozur and Mostler, 1981 emended Dumitrica s original diagnosis, however, the author is using the definition of Dumitrica as it offers the clearest method of distinction of this group.

Genus ***PENTACTINOCARPUS*** Dumitrica, 1978.

Type species: Pentactinocarpus fusiformis Dumitrica, 1978

1979 *Oertlisphaera* Kozur and Mostler, 1979

Original description: (of Dumitrica, 1978) Globular and spindle-shaped single latticed shell with the pentactine spicule at the apical end and commonly a spine at the antapical one. Apical spine simple, conical; the four basal spine cylindrical and inserted in the upper part of the latticed shell, except for the proximal portions which delineate four large triangular or subtriangular openings.

Range: Upper Triassic (lower Ladinian-Rhaetian as far as known).

Occurrence (literature): Italy, Romania, Queen Charlotte Islands, British Columbia, Philippines, Japan.
Occurrence (this study): W. Timor, Indonesia.

Remarks: (Dumitrica, 1978) remarks that the genus *Pentactinocarpus* is one of the most common Palaeoscenidiids of the Middle and Upper Triassic. This genus appears to be closely related to *Pentactinocapsa* Dumitrica, 1978 with its simple test and basal skeleton. A ring separating the latticed shell from the proximal portions of the basal spines probably resulted from the fusion of the basal spines and is likely to have formed the basis of the latticed shell .

Pentactinocarpus aspinosus Kozur and Mostler, 1981
Pl. 9, figs. 1, 2, 3, 11.
Cat. Nos. 3020/18, 3015/17, 3020/17, 3251/34.

*1981 *Pentactinocarpus aspinosus* Kozur and Mostler, Pl. 53 fig. 3.

Original description: (of Kozur and Mostler, 1981 p. 20) Schale subspharisch bis subellipsoidal. Apicaler Teil der Schale kegelformig. Apicaler und antapicaler Dorn kurz und zart. Apicalporen relativ klein. Die Basalstacheln sind unterhalb des Proximalringes ganzlich in die schale eingeschlossen. Laterale Stacheln an den Distalenden der Basalstacheln treten daher nicht auf.

Schale sehr grobporig mit regelmassig rechteckigen Poren. Auf den Kreuzungspunkten der Gitterbalken befinden sich klein runde Knotchen oder kurze stumpfe Dornen.

Dimensions (microns):	Average of 10 specimens	max.	min.
Total length of test	440	453	421
Width of test	347	352	341
Length of apical spine (if present)	27	41	18

Material: 13 specimens

Range: Upper Triassic (Carnian-Rhaetian as far as known).

Occurrence (literature): Romanian Carpathians, Slovakia, Austria, Italy.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 231, Sample 232, Sample 220).

Remarks: The holotype of Kozur and Mostler, 1981 are infilled and generally poorly preserved. Specimens recovered in this study are well-preserved, and comparisons are easily made. The overall shape is similar, but perhaps a little more spherical than the holotype. Pores are variably sized in Kozur and Mostler (1981) figured specimens and have more prominent nodes at the pore frame vertices.

Pentactinocarpus longispinosis n. sp.
Pl. 9, figs. 6, 7, 9, 10.
Cat. Nos. 3020/19 = Holotype fig. 6, Paratypes =3251/38, 3251/36, 3251/35, figs. 7, 9, 10.

Diagnosis: This species of *Pentactinocarpus* is distinguished from others by having long apical bar with a flattened test between the bars proximally.

Description: Test subspherical. Apical spine long and tapering with four radially arranged spines which continue onto the latticed part of the shell forming straight rods terminating in distally pointing spines at approximately halfway between the apical and antapical spines. Latticed shell consists of two groups of pore sizes, the first being irregular and always in contact with the four radially arranged apical rods, the other group being more uniformly sized (with hexagonal pore frames) and not in contact with the extended apical rods. the distal part of the latticed shell forms an almost perfectly hemispherical shape. A long antapical spine is present, however, this is only rarely preserved.

Dimensions (microns):	Average of 10 specimens	max.	min.	Holotype
Total length of test	353	360	342	357
Width of test	290	296	280	285
Length of apical spine (if present)	110	129	89	94

Material: 13 specimens

Range: Upper Triassic (Carnian-Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 231, 232, 223).

Etymology: longispinosis refers to the long apical bars.

Type locality: River Soe sections, West Timor, Sample 231, 232, 223 (see Chapter 4 log sections).

Remarks: Pentactinocarpus longispinosis may be distinguished from *P. magnus* Kozur and Mostler, 1979 by having apical bars that continue onto the latticed shell and terminate in antapically pointing spines, and also by having generally smaller pores relative to the shell size. *P. longispinosis* also differs from *P. acanthocircus* Dumitrica, 1978 and *P. tetracanthus* Dumitrica, 1978 by having more regular pore frames and by having an apical area which is flattened between the for rods.

Pentactinocarpus sevaticus Kozur and Mostler, 1981.
Pl. 9, figs. 4, 5.
Cat. Nos. 3251/6, 3208/32.

*1981 *Pentactinocarpus sevaticus* Kozur and Mostler in Kozur and Mostler, 1981, p. 21-22, Pl. 52, fig.3, Pl. 53, fig. 2, Pl. 55, fig. 1.
1993 *Pentactinocarpus* sp. cf. *P. sevaticus* Kozur and Mostler; Carter p. 40, Pl. 1, figs. 11, 15, Pl. 21, figs. 15, 17.

Original description: (of Kozur and Mostler, 1981 p. 21-22) Schale subspharisch bis subellipsoidal. Apicalstachel kurz und zart. Auch der antapicale Stachel ist nur kurz. Apicalporen gross. Basalstacheln vollig in die Schalenwald eingebaut und dabei dem Verlauf der Gitterbalken angepasst (zickzackformig). Die Distalenden der Basalstacheln bilden jeweils einen kurzen Stachel. Einer dieser Stacheln ist in eine spitz-dachformige Aufragung mit grosser basaler Pore umgewandelt.

Dimensions (microns):	Average of 8 specimens	max.	min.
Total length of test	392	438	345
Width of test	245	290	195
Length of apical spine (if present)	21	35	10

Material: 11 specimens

Range: Upper Triassic (upper Norian-Rhaetian).

Occurrence (literature): European alps, Queen Charlotte Islands.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: Pentacinocarpus sevaticus differs from other species of *Pentactinocarpus* by having a distinctly ovoid-shaped test.

Pentactinocarpus sp. A
Pl. 9, fig. 8.
Cat. No. 3078/33.

Description: Apical spine long. Shell subcylindrical, subpyrimoidal at the distal end, middle portion parallel sided, distal end hemispherical in shape. Four latteral spines radially arranged at approximately one third of the way to the antapical spine. Pores, subcircular surrounded by polygonal (mainly hexagonal) pore frames. Antapical spine triangular in outline, tapering to a short rod circular in axial section.

Dimensions (microns):	Average of 5 specimen	max.	min.
Total length of test	241	246	230
Width of test	129	139	123
Length of apical spine (if present)	66	73	59

Material: 5 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 232).

Remarks: Pentactinocarpus sp. A differs from other species of *Pentactinocarpus* by having an elongate subcylindrical test.

Subfamily **SYRINGOCAPSINAE** Foreman 1973.

Type genus: Syringocapsa Neviani, 1900 p. 662.

Original description: (of Foreman, 1973 p. 265) Cyrtoidea with the multiple segments of the proximal part very small and the single segment of the distalmost part very large and expanded. A terminal tube may or may not be present. None of the proximal segments are hidden and the cryptocephalic cryptothoracic nassellria of Dumitrica (1970) are therefore excluded. Constituent genera are: *Dibolachras* Foreman, 1973; *Podocapsa* Rust, 1885; *Podobursa* Wisniowski, 1889, emend. Foreman 1973; *Sethocapsa* Heackel, 1881; *Syringocapsa* Neviani, 1900; *Trisyringium* Vinassa, 1901-1902; *Urocyrtis* Pantanelli, 1880.

Range: Upper Triassic-Cenozoic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Dibolachras Foreman, 1973 *Syringocapsa* Nevianni, 1900, *Podocapsa* Rust, 1885; *Podobursa* Wisniowski, 1889 emend. Foreman, 1973 *Sethocapsa* Heackel, 1881 *Trisyringium* Vinassa, 1901-1902.

Remarks: The basis for the division of this long-ranging subfamily is the number of external spines observed around the periphery of the abdominal chamber.

Genus ***DIBOLACHRAS*** Foreman, 1973.

Type species: Didolachras tytthopora Foreman, 1973.

Original description: (of Foreman, 1973 p. 265) The shell is of three or four (?) segments, the small proximal part made up of all but the large distalmost segment which expanded and bears only two spines and a porous terminal tube.

Range: Upper Triassic-?Cenozoic

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Foreman (1973 p. 265) points out that the difference between *Dibolachras* and *Podobursa* is that the former has only two spines.

Dibolachras sp. A
Pl. 22, fig. 6.
Cat. No. 3053/31.

Description: Cephalis and thorax small and smooth. Abdomen large spherical with two spines perpendicular to the long axis of the test. Abdomen covered with subcircular pores surrounded by polygonal pore frames. The distal end consists of a thin tube covered in pores with irregular pore frames and terminates in shorter, thinner tube at the distal tip

Dimensions (microns):	Average of 6 specimens	max.	min.
Total length of test	407	420	390
Width of test (expanded chamber)	218	220	214
Length distal tube	270	274	262

Material: 8 specimens

Range: Upper Triassic (lower-middle Norian, as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 246, 223).

?***Dibolachras*** sp. B
Pl. 22, fig. 12.
Cat. No. 3078/36.

Description: Cephalis and thorax smooth and moderate in size. Abdomen large and inflated with two lateral spines on the central area. Abdomen covered with subcircular pores. The distal end consists of a thin tube with strictures at its terminal end.

Dimensions (microns):	Average of 4 specimens	max.	min.
Total length of test	612	620	593
Width of test (expanded chamber)	179	185	172
Length distal tube	331	348	320

Material: 4 specimens

Range: Upper Triassic (Norian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: This species differs from other of *Dibolachras* by having strictures on the distal tube.

Genus *SYRINGOCAPSA* Neviani, 1900.

Type species: (by monotypy) *Theosyrium robustum* Vinassa de Regny, 1900b. *Trisyringium* Vinasssa, 1901-1902, p. 507. Type species (subsequent designation by Cambell 1954, p. D142) *Trisyringium capellini* Vinassa, 1901-1902.

Description: (not original) Three or four segmented forms. Cephalis small, spherical with or without an apical horn. Distal segment constricts into a long, narrow tube.

Range: Upper Triassic (Carnian/Norian) to Lower Cretaceous (Barremian)

Occurrence (literature): Worldwide Tethyan and Boreal Realms.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Blome (1988) distingiushes *Syringocapsa* from *Podobursa* Wisniowski, 1889, *Podocapsa* Rust, 1885, and *Dibolachras* Foreman, 1973, by lacking radially arranged spines situated on the abdomen and first postabdominal chamber. Foreman (1973 p. 268) states that *Trisyringium capellini* and *Theosyringium robustum* differ from each other only in that *T. capellini* bears a horn. This is not considered significant at generic level and the two genera are thus synonymised.

Syringocapsa batodes De Wever, 1979
Pl. 22, figs. 2, 3, 4, 7, 8, 9, 10.
Cat. Nos. 3053/32, 3053/28, 3053/25, 3053/27, 3053/23, 3251/14.

*1979 *Syringocapsa batodes* De Wever in De Wever *et al.*, Pl. 6, figs. 10-12.
1979 Unnamed Podobursa-like nassellarian Pessagno, Pl. 4, fig. 7.
1982 *Syringocapsa batodes* De Wever; Matsuoka and Nakatani, Pl. 1, fig. 18.
1991 *Syringocapsa batodes* De Wever; Bragin, p.106.Pl. figs. 4, 5.

Original description: (of De Wever, 1979 p. 91) Four segmented form with an inflated middle section. Upper portion of the shell formed of three small, poreless or sparsley porous segments, the cephalis with a horn. Fourth segment large and globular proximally, abruptly constricting to a narrow tube distally. This large segment has moderately irregular pores, and a spiney surface.

Dimensions (microns):	Average of 10 specimens	max.	min.
Total length of test	418	421	415
Width of test (expanded chamber)	169	175	165
Length distal tube	219	223	213

Material: 45 specimens

Range: Upper Triassic (lower-middle Norian).

Occurrence (literature): Greece, Turkey, Japan.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 246, 239, 223, 216-217-218).

Remarks: These specimens have a slightly more spherical fourth chambers than the holotype of De Wever (1979)

Syringocapsa sp. aff. ***S. batodes*** De Wever, 1979
Pl. 22, fig. 11.
Cat. No. 3020/3.

aff. *1979 *Syringocapsa batodes* De Wever in Wever *et al.*, Pl. 6, figs. 10-12.
aff.1979 Unnamed Podobursa-like nassellarian Pessagno, Pl. 4, fig. 7.

aff.1982 *Syringocapsa batodes* De Wever; Matsuoka and Nakatani, Pl. 1, fig. 18.
aff.1991 *Syringocapsa batodes* De Wever; Bragin, p.106, Pl. figs. 4, 5.

Original description: (of De Wever, 1979 p. 91) Four segmented form with an inflated middle section. Upper portion of the shell formed of three small, poreless or sparsley porous segments, the cephalis with a horn. Fourth segment large and globular proximally, abruptly constricting to a narrow tube distally. This large segment has moderately irregular pores, and a spiney surface.

Dimensions (microns):	Average of 5 specimens	max.	min.
Total length of test	370	375	367
Width of test (expanded chamber)	152	159	146
Length distal tube	160	162	155

Material: 5 specimens

Range: Upper Triassic (lower-middle Norian as far as known).

Occurrence (literature): Greece, Turkey, Japan.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: *S.* sp. aff. *S. batodes* differs from *S. batodes* by having a bulge at the distal end of the terminal tube

?***Syringocapsa*** sp. A
Pl. 22, figs. 1, 5.
Cat. No. 3053/26.

Description: Small, smooth and conical-shaped cephalis, thorax and abdomen; post-abdominal chamber is slightly inflated with a conical outline; this inflated chamber covered in irregular pores surrounded by pore frames with nodes at the pore frame vertices; distal end of chamber is constricted into a narrow tube which tapers distally, and is covered in small irregular pores.

Dimensions (microns):	Average of 4 specimens	max.	min.
Total length of test	380	382	378
Width of test (expanded chamber)	118	123	117
Length distal tube	169	182	163

Material: 4 specimens

Range: Upper Triassic (lower-middle Norian as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: This species differs from *S. batodes* by having post-abdominal chamber with a conical outline thus is questionably assigned to the genus *Syringocapsa.*

Genus ***TIRODELLA*** Kozur and Mostler, 1981.

Type species: Tirodella goestlingenesis Kozur and Mostler, 1981

Original description: (of genus and type species of Kozur and Mostler, 1981 p. 112) Dicyrtid. Cephalis sehr klein, subellipsoidal bis subspharisch, unpperforiert. Dreikantiges Apicalhorn sehr kraftig. Thorax kugelformig, sehr gross, mit unregelmassigen, mittelgrossen Poren. In verlangerung dieser sieben dunnen Thoraxfusse treten kraftige Rippen auf der Thoraxwand auf. Munoffnung gross. Cephalisches Spicularsystem mit A, D, V, L, I.

Range: Upper Triassic (as far as known).

Occurrence (literature): Austria, Italy, Slovakia, hungary.
Occurrence (this study): W. Timor, Indonesia.

Remarks: The generic description is the same as the species description.

Tirodella goestlingensis Kozur and Mostler, 1981
Pl. 25, fig. 8.
Cat. No. 3057/5.

* 1981 *Tirodella goestlingensis* Kozur and Mostler in Kozur and Mostler, Pl. 8, fig. 1.

Original description: (of genus and type species of Kozur and Mostler, 1981 p. 113) Dicyrtid. Cephalis sehr klein, subellipsoidal bis subspharisch, unpperforiert. Dreikantiges Apicalhorn sehr kraftig. Thorax kugelformig, sehr gross, mit unregelmassigen, mittelgrossen Poren. In verlangerung dieser sieben dunnen Thoraxfusse treten kraftige Rippen auf der Thoraxwand auf. Munoffnung gross. Cephalisches Spicularsystem mit A, D, V, L, I.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of distal spines	86	94	74
Test length	381	392	376

Material: 4 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Austria, Italy, Slovakia, hungary.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232).

Remarks: The specimen recovered from Timor though poorly preserved still closely resembles the holotype of Kozur and Mostler, 1981.

Family **XIPHOTHECIDAE** Kozur and Mostler, 1981.

Type genus: Xiphotheca De Wever, 1979

Original description: (of Kozur and Mostler, 1981 p. 113) Ungewohnlich lange, sehr schanke Radiolaria. Abdomen, seiten erstes postabdominales Segment am grossten. Zahl der etwa gleich breiten postabdominalen Segmente variabel, miximal wurden elf beobachtet. Die ersten postabdminalen segmente konnen zylinderformig ohne Einschnurungen sein.

Range: Upper Triassic (as far as known).

Occurrence (literature): Worldwide.
Occurrence (this study): W. Timor, Indonesia.

Included genera: Xiphotheca De Wever, 1979.

Original remarks: This family differs from others by having a bulbous post-abdominal chambers which

Genus *XIPHOTHECA* De Wever, 1979.

Type species: Xiphotheca karpenissionensis De Wever, 1979

Original description: (of De Wever, 1979 p. 93) Very long, subcylindrical forms (approximately 0.5mm), with the two ends showing a tendency to segmentation, and a long central portion simply tubular. Pores tend to be longitudinally aligned.

Range: Upper Triassic (as far as known).

Occurrence (literature): Worldwide.
Occurrence (this study): W. Timor, Indonesia.

Remarks: De Wever states that this genus is the only known radiolarian genus with such a long skeleton. Variations within this genus appear to concern the size and shape of the cephalis, thorax and abdomen and the number of post-abdominal chambers.

Xiphotheca longa Kozur and Mostler, 1981
Pl. 23, figs. 10, 11.
Cat. Nos. 3045/20, 3045/22.

*1981 *Xiphotheca longa* Kozur and Mostler in Kozur and Mostler, Pl. 41, fig. 2.

Original description: (of Kozur and Mostler, 1981 p. 113) Ungewohnlich lange, schlanke Radiolaria. Cephalis klein, konisch, unperforiert. Thorax nur wenig grosser mit ei zelnen kleinen Poren. Abdomen deutlich grosser als alle anderen Segmente, reifenartig, mit zahlreichen kleinen Poren. Postabdomale Segmente alle etwa gleich gross, kleiner als Abdomen. Sie sind perlschnurartig aufgereiht undweisen kleine, unregelmassige Poren auf. Das letzte Segment ist geringfugig breiter und wenig niedriger als die vorhergehenenden.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of abdomen	75	72	78
Length of test	521	531	501

Material: 19 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Hungary, Austria, Italy, Slovakia.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 223).

Remarks: The cephalis, thorax and abdomen, at first sight, look similar to *Xiphotheca karpenissionensis* De Wever, 1979, however, the post abdominal chambers are regularly constricted with the inflations very gradually reducing in size toward the distal termination.

Xiphotheca sp. aff. ***X. longa*** Kozur and Mostler, 1981.
Pl. 23, fig. 7.
Cat. No. 3045/19.

aff.*1981 *Xiphotheca longa* Kozur and Mostler in Kozur and Mostler, Pl. 41, fig. 2.

Original description: (of Kozur and Mostler, 1981 p. 113) Cephalis smooth, conical without distinctive pores. Thorax, larger and a smooth continuation of the cephalis. Abdomen, rounded, with distinct pores and is the widest part of the test. Post-abdominal chambers (seven) gradually reduce in diameter, are rounded in outline with strictures between each chamber. Last and smallest post-abdominal chamber terminates in a cylindrical tube.

Dimensions (microns):	Average of 10 specimens	max.	min.
Diameter of abdomen	78	82	75
Length of test	474	483	458

Material: 10 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Hungary, Austria, Italy, Slovakia.
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 232, 223).

Remarks: This species is rather similar to *X. longa* Kozur and Mostler, 1981, however, the post abdominal chambers are fewer in number, are relatively large when compared to the cephalic end and these chambers are more rounded in ouline compared to those of *X. longa.*

Xiphotheca sp. A
Pl. 23, fig. 8.
Cat. No. 3073/1.

Description: Cephalis and thorax form a smooth conical area without pores. Abdomen comprises widest part of the test, is ovate and may well be porate (preservation is poor). Post abdominal chambers consist of a series of inflations. Proximally the inflations are longer than broader, however, the length of the inflations is reduced distally until the final three chambers are not as long as wide. The central part of the post abdominal tube has the narrowest diameter and is cylindrical in axial section.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of abdomen	73	76	69
Length of test	462	471	442

Material: 10 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample 246, 233-234, 223).

Remarks: This species is unusual in that it has proximally large and distally small post abdominal chambers.

Xiphotheca sp. B
Pl. 23, fig. 9.
Cat. No. 3045/15.

Description: Cephalis thorax and abdomen smooth and gradually increasing in width. Post abdominal chambers consist of four chambers with constrictions at the joints; post abdominal chambers reduced in size distally and terminates in a short cylindrical tube.

Dimensions (microns):	Average of 7 specimens	max.	min.
Diameter of abdomen	119	124	117
Length of test	556	570	523

Material: 7 specimens

Range: Upper Triassic (Norian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 223).

Remarks: *X.* sp. B differs from other examples of the genus *Xiphotheca* by having only four post-abdominal chambers.

Family **PSEUDOSATURNIFORMIDAE** Kozur and Mostler, 1979.

Original description: (of Kozur and Mostler, 1979 p. 91) Radchenformige monocyrtide Skelette. Cephalis gross, hemiellipsoidal mit feinkorniger bis dichter Rinde. An der Mundoffnung stetzen 6 speichen an, die zu einem unterschiedlich breiten kreisförmigen Ring laufen, wobei 6 gross offnungen eingeschlossen werden. Die cephalischen skelettemente bestehen aus vertikalem, dorsalem, apicalem, mdianem, primaren und sekundären links- und rechslateralen Balken; sie schliessen 6 collarporen ein.

Range: Upper Triassic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera: Pseudosaturniforma Kozur and Mostler, 1979.

Remarks: This family differs from other saturnalids by possessing a spicular system and a dicyrtid test.

Genus ***PSEUDOSATURNIFORMA*** Kozur and Mostler, 1979.

Type species: Pseudosaturniforma latimarginata Kozur and Mostler, 1979.

Original description: (of Kozur and Mostler, 1979 p. 91) Radchenformige monocyrtide Skelette. Cephalis gross, hemiellipsoidal mit feinkorniger bis dichter Rinde. An der Mundoffnung stetzen 6 speichen an, die zu einem unterschiedlich breiten kreisformigen Ring laufen, wobei 6 gross offnungen eingeschlossen werden. Die cephalischen skelettemente bestehen aus vertikalem, dorsalem, apicalem, mdianem, primaren und sekund ren links- und rechslateralen Balken; sie schliessen 6 collarporen ein.

Range: Upper Triassic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs from saturnalid-like Nassallariina by being monocyrtid and by having the cephalis and cephalic ring situated in more than one plane.

Pseudosaturniforma carnica Kozur and Mostler, 1979.
Pl. 17, figs.7, 8, 9, 10.
Cat. Nos. 3020/27, 3057/2, 3020/28, 3020/26.

*1979 *Pseudosaturniforma carnica* Kozur and Mostler in Kozur and Mostler, p. 92, Pl. 17, fig 3.
1984 *Pseudosaturniforma carnica* Kozur and Mostler; Blome, Pl.13, figs. 5, 9, 11, 18.

Description: (of Kozur and Mostler, 1979 p. 92) Mit den Gattungsmerkmalen. Rander der Ringstruckur schmalaussen aufgeschlagen. Speichen schmal und lang. Eingeschlossene offnungen sehr gross, gerundet trapezf rmig.

Dimensions (microns):	Average of 8 specimens	max.	min.
Width of ring	37	38	35
Diameter of ring	136	145	130
Diameter of cephalis	72	67	84

Material: 8 specimens

Range: Upper Triassic (Norian).

Occurrence (literature): Western North America, Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232).

Remarks: This species differs from others by having a relatively broad ring and a moderately small cephalis.

Genus ***TRIASSOCAMPE*** Dumitrica, Kozur and Mostler, 1980.

Type species: Triassocampe scalaris Dumitrica, Kozur and Mostler, 1980.

Description: (for a description see Kozur and Mostler, 1980)

Range: Middle-Upper Triassic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs from *Dictyomitrella* by having more than one row of pores.

Triassocampe? sp. aff. ***T. scalaris*** Dumitrica, Kozur and Mostler, 1980.
Pl. 26, fig. 8.
Cat. No. 3747/27.

aff.*1980 *Triassocampe scalaris* Dumitrica, Kozur and Mostler in Dumitrica, Kozur and Mostler, 1980 p. Pl, fig.

Original description: (of Dumitrica, Kozur and Mostler, 1980) Shell of 9-15 preserved segments, without apical horn. Cephalis and even thorax poreless with smooth surfaces. Collar stricture almost indistinct outside. Generally the pores begin with the third segment. They are arranged in 2-4, commonly three transverse rows. At the nodal points among the pores they are rather well-developed nodules. Between the first two rows of nodules that correspond with the widest part of the segments, and the second row there is a circular external constriction. Another constriction, the deepest one, is at the lower part of segments and it corresponds with an inner constriction .

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of test	257	261	254
Diameter of test (widest)	71	78	67

Material: 4 specimens

Range: Middle-Upper Triassic (as far as known).

Occurrence (literature): Europe, Philippines.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232).

Remarks: This species of *Triassocampe* differs from others by having relatively wide chambers which are upturned trapezoidal in outline.

Family **NEOSCIADIOCAPSIDAE** Pessagno, 1969.

Genus ***CITRIDUMA*** De Wever, 1982.

Type species: Citraduma radiotuba De Wever, 1982.

Original description: (of De Wever, 1982) Neosciadiocapsidae dont le squelette cephalique est form de 8 actines (A, V, D, mB, L, I, I_1 et I_2) la presence due cephalis sur l'une des faces permet de distinguer une face superieure et une face inf rieure. Le cephalis hemisperique, porte unecorne apicale et une corne lateral respectivement situees dans le prolongement des actines A et V du squelettec phalique. Le thorax, ferme la partie inferieure, confere ce genre une allure discoide, il possede des tubes lat raux.

Range: Upper Triassic to Lower Jurassic (as far as known).

Occurrence (literature): California, Oregon, Europe, Japan.

Occurrence (this study): W. Timor, Indonesia.

Remarks:This genus differs from *Livarella* by having more than three arms and by having a larger discoidal central body.

Citraduma sp. A
Pl. 14, fig.4.
Cat. No. 3100/6.

1993 *Citraduma* sp. A, Carter, p. 97, Pl. 15, figs. 1, 4.

Description: Very large, perforate test with eight radial tubes, each tube rounded and conical . Underside of the test with raised circular platform.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of arms	89	95	84
Diameter of central test	264	270	258

Material: 6 specimens

Range: Upper Triassic (Rhaetian).
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 224).

Remarks: This species is probably the same as *Citraduma* sp. A Carter, 1993 Pl. 15, figs. 1, 4.

Citraduma sp. B
Pl. 14, fig. 5.
Cat. Nos. 3100/5.

1992 Unnamed 6-livarellid Yeh, Pl. 3 fig. 6.
1993 *Citraduma* sp. C Carter, p. 98, Pl. 15, figs. 12, 13, 14, 17.

Description: Large test with six slender, tapering radial arms. Cephalis small and finely perforate, thorax composed of larger, irregular pore frames.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of arms	154	163	148
Diameter of central test	190	204	184

Material: 5 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 224).

Remarks: This form of *Citraduma* is very similar to *Citraduma* sp. C, Carter, 1993 (Pl. 15, fig. 12, 13, 14, 17).

Citraduma sp. C
Pl. 14, fig. 6.
Cat. Nos. 3100/4.

Description: Large test with eigth short, triangular radial rays. Thorax large and moderately coarsely perforate, cephalis finely perforate.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of arms	47	52	41
Diameter of central test	321	339	305

Material: 4 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: This form of *Citraduma* is similar to *Citraduma* sp. B, Carter, 1993 (Pl. 15, fig. 2) differing in the size of the pores on the thorax and by having broad peripheral spines, as opposed to narrow ones.

Genus *SQUINABOLELLA* Pessagno, 1969.

Non *Squinabolella* Kozur, 1979.

Type species: Squinabolella putahensis Pessagno, 1969.

Original description: (of Pessagno, 1969) Hat-shaped dicyrtid test. Hemispherical cephalis has an apical horn with four apical pores at the base and a cephalopyle. Cephalis contains nine cephalic skeletal elements. Thorax large, conical proximally, flaring distally to a broad thoracic skirt. Thoracic velum well-developed.

Range: Upper Triassic-Cretaceous (as far as known).

Occurrence (literature): California, Oregon, Europe, Japan.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Squinabolella differs from ***Ruesticyrtium*** by having less than eight chambers and a bulbous proximal area. Carter, 1993 noted that as *Squinabolella* n. gen. Kozur, 1979 described a form with longer thorax with a brim and spines than *Squinabolella* Pessagno, 1969 and as the genus of Kozur, 1979 was proposed ten years later than that of Pessagno it was therefore invalid. Species described by Carter, 1993 did not contain a cephalopyle as mentioned in the original diagnosis.

Squinabolella*? *maxima n. sp.
Pl. 23, figs. 12, 13, 14.
Cat. Nos. 3208/5 = Holotype figs. 12, 14, Paratype =3208/10, fig. 13.

Diagnosis: This species of *Squinabolella*? is distinguished by a very broad thoracic skirt.

Description: Test probably dicyrtid. Cephalis smooth without a visible horn. Thorax small and conical with a spongy covering giving way to large, concentric, circular pores. The thoracic skirt very large and almost flat, gently curling downward. Pores on the thoracic skirt increasing in size distally. Small vellum attached to the inside of the thoracic skirt and not visible from the sides.

Dimensions (microns):	Average of 8 specimens	max.	min.	Holotype
Diameter of test	421	435	391	427
Length of test	187	209	163	167
Diameter of final chamber - (without thoracic skirt)	212	224	202	212

Material: 14 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 224).

Etymology: maxima refers to the large size of the thoracic skirt.

Type locality: River Meto sections, West Timor, Sample 220, 224 (see Chapter 4 log sections)

Remarks: Squinabolella? *maxima* n. sp. differs from other species of *Squinabolella* by having a very broad thoracic skirt.

Squinabolella? sp. aff. ***S. causia*** Carter, 1993.
Pl. 24, fig. 5.
Cat. No. 3747/2.

aff.*1993 *Squinabolella causia* Carter in Carter, p. 100, Pl. 16, figs. 5, 8, 12, 14.

Original description: "(of Carter, 1993 p. 100) Cephalis small and conical with slim apical horn. Thorax large, hemispherically-elongate proximally; abruptly expanding distally to form a narrow thoracic skirt. Meshwork of cephalis and thorax (excepting thoracic skirt) multilayered; inner layer consisting of large circular pore frames, outer layer with smaller pore frames arranged dendrically. Thoracic skirt composed of a single layer of large circular pores. Rim of thoracic skirt edged with two rows of small rounded nodes. Thoracic velum gently angled downward, composed of irregular meshwork similar to that of cephalis and thorax.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of test	364	378	352
Diameter test (widest)	186	192	181
Diameter of thoracic skirt	265	269	258

Material: 4 specimens

Range: Upper Triassic (Rhaetian as far as known).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Ocurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 224).

Remarks: This form differs slightly from *S.* sp. aff. *S. causia* Carter, 1993 by having a more elongate test and a narrow skirt.

Squinabolella*?** sp. aff. ***S. desrochersi Carter, 1993.
Pl. 24, fig. 11.
Cat. No. 3015/18.

aff.*1993 *Squinabolella desrochersi* Carter in Carter, p. 101, Pl. 16, figs. 3, 4, 6, 7, 9, 10, 12, 13.

Original description: "(of Carter, 1993 p. 101) Cephalis hemispherical with short, cylindrical apical horn. Thorax large, conical proximnally; flaring distally to form a broad thoracic skirt. Two layers of meshwork present on cephalis and thorax, but thoracic skirt has a single layer of large circular pores. Inner layer of meshwork perforate with pores enlarging distally; outer layer dendritically arranged. Rim of thoracic skirt smooth, bounded by a double ridge. Thoracic velum directed downward, composed of irregular meshwork similar to that of cephalis and thorax.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of test	186	194	178
Diameter test (widest)	136	147	129
Diameter of thoracic skirt	268	271	255

Material: 6 specimens

Range: Upper Triassic (Norian/Rhaetian as far as known).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 223).

Remarks: S. sp. aff. *S. desrochersi* differs from *S. desrochersi* Carter, 1993 by having heavier irregular meshwork on the cephalis and thorax. This form is found in older samples of Norian age unlike the Rhaetian forms of Carter (1993).

Squinabolella? sp. aff. ***S. trispinosa*** Carter, 1993.
Pl. 24, fig. 4.
Cat. No. 3251/1.

aff.*1993 *Squinabolella* ? sp. aff.*trispinosa* Carter in Carter, p. 102, Pl. 17, figs. 3, 4.

Original description: (of Carter, 1993 p. 102) Test probably dicyrtid. Cephalis large, conical with strong triradiate horn. Thorax long and conical, gradually widening distally and flaring abrupt at base to form narrow thoracic skirt with finely nodose rim. Three short triradiate spines, representing the elements of the internal spicule, extending outward radially from juncture of cephalis and thorax. Meshwork of cephalis and thorax composed of two or more layers of fine irregular pore frames. A ridge of relatively large, deep pore frames surrounds base of apical horn. Test has prominenet downwardly-directed thoracic velum composed of irregular meshwork similar to that of thorax. Oral opening circular.

Dimensions (microns):	Average of 7 specimens	max.	min.
Length of test	341	353	332
Diameter test (widest)	173	184	169
Diameter of thoracic skirt	241	247	237

Material: 7 specimens

Range: Upper Triassic (?Norian/Rhaetian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noile Meto, Soe, West Timor, Indonesia (Sample 231).

Remarks: Carter, 1993 queried the genus because of the presence of three spines at juncture of cephalis and thorax. The presence of three spines is found in other similar forms recovered during this study. The age of these specimens is older than those of Carter (1993)

Family **DEFLANDRECYRTIIDAE** Kozur and Mostler, 1979.

Type genus: Deflandrecyrtium Kozur and Mostler, 1979

Original description: (of Kozur and Mostler, 1979 p. 95) Tricyrtid, z. T. tetracyrtid. Cephalis kugelig bis konisch, imperforat oder mit wenigen Poren. Mit oder ehne Apicalhorn. Thorax mehr oder weniger deutlich vom cephalis abgesetzt, wesentlich breiter als dieser. Abdomen unterschiedlich lang, distaltrichter-bis scheibenformig verbreitert und hier mit grossen, ringformig angeordneten Poren, mit oder ohne Randstacheln. Mundoffnung rund, sehr gross. Cephalisches Spicularsystem kraftig ausgebildet mit apicalem, dorsalem, medianem, vertikalem, prim ren und sekund ren rechts- und linkslateralen Balken, randlich nicht gegabelt. 6 collarporen.

Range: Upper Triassic.

Occurrence (literature): European Tethys.
Occurrence (this study): West Timor, Indonesia

Included genera: Deflandrecyrtium, not *Dreyericyrtium, Haeckelicyrtium, Goestlingella* from Kozur and Mostler (1979).

Remarks: Differs from the Squinabolellidae by being tri-tetracyrtid as opposed to being dicyrtid.

Genus ***DEFLADRECYRTIUM*** Kozur and Mostler, 1979.

Type species: Deflandrecyrtium popofsky Kozur and Mostler, 1979.

Original description: "(of Kozur and Mostler, 1979 p. 96) Cephalis konisch, in einen schmaleren oberen und in einen breiteren unteren Teil zweigeteilt, wobei das spicularsystem im breiteren unteren Teil liegt. Apicalhorn vorhanden. Wandung berwiegend imperforat, manchmal mit einzeinen Poren, besonders unterhalb dae

Apicalhorns. Thorax wesentlich breiter, grobporig, wobei, die Poren besonders proximal durch eine zweite schicht weitgehend verschlossen sind. Abdomen kurz, distal trichterförmig erweitert, mit grossen, etwa konzentrisch angerordneten Poren. Distalrand mit Randstacheln unterschiedlicher Lange besetzt, die im allgemeinen schräg nach aussen und unten gerichtet sind. Spicularsystem wie bei der Familie.

Range: Upper Triassic.

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): West Timor, Indonesia.

Remarks: Kozur and Mostler (1979) introduced the genus *Dreyericyrtium,* however, in their 1981 publication appear to have questioned the validity of *Dreyericyrtium* and made into a junior synonym of *Deflandreyrtium.*

Deflandrecyrtium kozuri n. sp.
Pl. 24, figs. 1, 3.
Cat. No. 3208/11 = Holotype figs. 1, 3.

Diagnosis: This species of *Deflandrecyrtium* is distinguished by its stout, smooth apical horn and well-developed abdominal pores.

Description: Cephalis conical with a stout, smooth apical horn. Thorax short and funnel-shaped. Abdomen slightly constricted medially then flares into a distal strongly perforated skirt. Abdomen composed of several layers, inner layer small circular to subcircular pores covered by a layer of irregular meshwork. The distal part of the abdomen which flares into a skirt comprises of one layer of larger ovoid pores which become more circular distally. The rim of the skirt is rounded and slighty thickened.

Dimensions (microns):	Average of 8 specimens	max.	min.	Holotype
Length of test	372	378	366	378
Diameter test (widest)	167	173	162	165
Diameter of thoracic skirt	331	345	324	443

Material: 9 specimens

Range: Upper Triassic (? Norian-Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor (Sample 220, 216-217-218).

Etymology: This species is named in honour of Dr. H. Kozur for his work on Triassic radiolarians.

Type locality: River Meto sections, West Timor (see Chapter 4 log sections)

Remarks: D. kozuri n. sp. differs from *D. nobense* Carter, 1993 by having a stout, smooth apical horn, very well-developed abdominal pores which become more circular distally and by having a distal rim which is thickened. This species is probably the same as *Dreyericyrtium* sp. A Yao, 1982 (Pl. 3, fig. 7).

Deflandrecyrtium*? *rhaetica n. sp.
Pl. 24, figs. 7, 9, 12.
Cat. Nos. 3208/7 = Holotype fig. 9, Paratypes =3208/3, 3208/2, figs. 7, 12 .

Diagnosis: This species of *Deflandrecyrtium* ? is distinguished by having an extremely long test.

Description: Cephalis conical with a short apical horn and three lateral spines occurring on one side of the test. Thorax long and funnel-shaped. Cephalis and thorax consists of two layers, the inner layer of larger circular pores with an outer layer of irregular meshwork. Abdomen long, almost cylindrical and flaring distally into perforate skirt. Skirt comprises of widely spaced circular pores and a thickened rim with two rows of nodes.

Dimensions (microns):	Average of 10 specimens	max.	min.	Holotype
Length of test	511	521	484	517
Diameter test (widest)	217	229	198	206
Diameter of thoracic skirt	448	457	428	435

Material: 15 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Etymology: rhaetica refers to the known age range of theis species.

Type locality: River Meto sections, West Timor (see Chapter 4 log sections)

Remarks: D.? rhaetica is similar to *Squinabolella? trispinosa* Carter, 1993 in that three lateral spines are present probably at the juncture of the cephalis and the thorax. The former differs from the species described by Carter (1993) by being much longer and more robust.

?***Deflandrecyrtium*** sp. A.
Pl. 24, fig. 2.
Cat. No. 3208/1

Description: Cephalis conical with short apical horn. Thorax long and funnel-shaped. Abdomen long, cylindrical terminating distally in a wide skirt. Test covered in irregular meshwork; small subcircular pores are more prominent on the distal part of the abdomen.

Dimensions (microns):	Average of 3 specimens	max.	min.
Length of test	389	397	384
Diameter test (widest)	156	161	152
Diameter of thoracic skirt	308	312	296

Material: 3 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: D. sp. A differs from other species of *Deflandrecyrtium* by having a long thorax and abdomen.

Deflandrecyrtium sp. B
Pl. 24, fig. 8.
Cat. No. 3208/8.

Description: Cephalis conical with a stout, smooth apical horn. Thorax short and funnel-shaped. Abdomen slightly constricted medially then flares into a distal perforated skirt. Abdomen composed of several layers, inner layer small circular to subcircular pores covered by a layer of irregular meshwork. The distal part of the abdomen which flares into a skirt comprises of one layer of circular to subcircular pores with wide imperforate areas in between. Distal skirt has a slightly thickened rim.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of test	291	295	287
Diameter test (widest)	128	132	125
Diameter of thoracic skirt	184	195	180

Material: 4 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: Deflandrecyrtium sp. B is similar to *Deflandrecyrtium* sp. A Carter, 1993, however, has less well-developed pores on the distal skirt.

Genus *SAITOUM* pessagno, 1977.

Type species: Saitoum pagei Pessagno, 1977.

Original description: (of Pessagno, 1977) Test small, monocyrtid with hemispherical cephalis having short hoen and three prominent feet. Massive cyrtoid cephalic skeletal elements visible at base of cephalis.

Range: Upper Triassic-? Lower Cretaceous (as far as known).

Occurrence (literature): Western North America.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus is characterised by having a subspherical test of irregular meshwork with three medially placed rays which bend distally.

Saitoum sp. A
Pl. 14, fig. 3.
Cat. No. 3251/10

Description: Central test subspherical and covered with irregular pore frames with nodes at the pore frame vertices. Three distally facing, triradiate (in axial section) rays attached around the middle or equator of the central test. The rays terminate in a spine.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of arms	164	172	151
Diameter of test	209	221	297

Material: 4 specimens

Range: Upper Triassic (upper Carian- Carnian/Norian boundary).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 223).

Remarks: This form is rare and generally poorly preserved.

Family **RUESTICYRTIIDAE** Kozur and Mostler, 1979.

Type genus: Ruesticyrtium Kozur and Mostler, 1979.

Original description: (of Kozur and Mostler, 1979 p. 100) Multicyrtidae, spitzbegelförmige Radiolarien mit 8-9 segmenten. Cephalis hemiellipsoidal imperforat, mit oder ohne kurzen Apicalhorn, mit oder ohne kurzen lateraldorn. Thorax und folgende segmente bis zum vorletzen segment schmal reifenförmig, wobei die Breite allmählich und gleichmassig zunimmt. Einschnürangen zmischen den segmenten kräftig, breiter als die segmente. Letzztes segment besonders gross und trichterförmig verbreitert. Distalrand glatt. Mundöffnung sehr gross rund. Wandung des cephalis und thorax imperforat in den folgenden segmenten kommen einige Poren oder Poren reihen in einer sonst imperforaten schale vor. Im Bereich der Einschnürungen ist die schale durchgehend imperforat. Letztes segment proximal mit einzelnen distal durchgehend mit sehr grossen, selten mässig grossen bis kleinen poren, die konzentrischen angeordnet sind. Cephalisches spicularsystem nicht bekannt.

Range: Upper Triassic

Occurrence (literature): Tethys of Europe.
Occurrence (this study): W. Timor, Indonesia.

Remarks: This Family differs from Squinabolidae by having conical test with eight or nine chambers.

Subfamily **RUESTICYRTINAE** Kozur and Mostler, 1979.

Genus ***PARARUESTICYRTIUM*** Kozur and Mostler, 1981.

Type species: Pararuesticyrtium densiporatum Kozur and Mostler, 1981.

Original description: (of Kozur and Mostler, 1981 p. 93-94) Multicyrtid, konisch, mit trichterförmig erweitertem letztem Segment. Cephalis hemiellipsoidal, ohne Poren, mit runlichem Apicalhorn und je einem rundlichen Horn in verlängerung von V und D. Segmente durch tiefe Einschnürungen voneinander abgetrennt. Einschnürungen stets unperforiert. Segmente mit zahireichen dicht stehenden mässig grossen bis grossen Poren. Cephalisches Spicularsystem mit Mb, A, D, V, L und I.

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe.
Occurrence (this study): West Timor, Indonesia.

Remarks: This distinctive genus differs from *Squinabolella* by having an elongate, cone-shaped test.

***Pararuesticyrtium*?** sp. A
Pl. 25, figs. 9, 10.
Cat. Nos. 3015/19, 3100/2.

Description: Multicyrtid with conical test. A small apical horn is present. Test perforated by large circular pores. Distal part of test flares out to form a moderately broad brim.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of test	216	228	208
Diameter of test	220	224	216

Material: 6 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 223, 220).

Remarks: This species differs from *P. rariporatum* Kozur and Mostler, 1981 by having large pores and lacks stricture at the chamber joints.

Genus ***WURANELLA*** Kozur and Mostler, 1981.

Type species: Wuranella carnica Kozur and Mostler, 1981.

Original description: (of Kozur and Mostler, 1981 p. 97) Multicyrtid, konisch, mit stark ausgeweitetem letzem Segment. Cephalis subellipsoidal bis subspharisch, mit breitem kurzem Apicalhorn und sehr kraftigen Stacheln in Verlängerung von V und I. Thorax, Reihe von grossen Poren. Tief eingesenkte Einschnürungen zwischen den Segmenten unperforiert. Letztes Segment im apialen Teil ebenfalls reifenartig, im distalen. Teil trichterformig verbreitert, mit liegen zwei Ringe von mittelgrossen bis grossen Poren, mitunter ist noch ein dritter Ring mit einzelnen Poren besetzt.

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs from *Pararuesticyrtium* by having three lateral proximal protrusions.

Wuranella carnica Kozur and Mostler, 1981.
Pl. 25, fig. 11.
Cat. No. 3074/8

*1981 *Wuranella carnica* Kozur and Mostler in Kozur and Mostler, p. 97, Pl. 19, fig. 2.

Original description: (of Kozur and Mostler, 1981 p. 97) Mit den Gattungsmerkmalen. Das apicalhorn ist dreikantig oder durche Auspaltung einer Kante z. T. auch vierkantig. Der gedrungene breiteVertikalstachel weist 4-6 Kantenauf. Die sehr grossen, vor allem breiten Dornen in Verl gerung von I besitzen drei Kanten. Die dreiKanten des Apicalhorns sind mit den Bögen AV und AI. Die Poren sind sehr symmetrisch angeordnet, je ein Porenring auf den reifenförmigen Segmenten und zwei Porenringe auf der trichterförmigen distalen Verbeiterung; ein dritter Ring kann hier durch Besetzung mit einzelnen Poren angedeutet sein.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of test	259	268	254
Diameter of test (widest)	137	139	135

Material: 5 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: This species is distinguished by the three lateral spines situated proximally.

Family **ENTACTINIIDAE** Riedel, 1967.

Genus ***ENTACTINOSPHAERA*** Foreman 1963.

Type species: Entactinosphaera esostrongyla Foreman 1963.

Original description: (of Foreman, 1963) Two or more well-developed, spherical or subspherical shells and an internal, six-rayed double spicule. When secondary spines are present, the six spines developed from the rays of the internal spicule are generally differentiated and recognisable as main spines.

Range: Palaeozoic to Mesozoic.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: The internal structure has not been studied therefore, forms are questionably assigned to the genus *Entactinosphaera.*

?***Entactinosphaera*** sp. A
Pl. 25, fig. 1.
Cat. No. 3054/15.

Description: Cortical shell spherical, moderate in size composed of a single layer irregular pore frames. spicules present at the pore frame vertices. Primary spines long and maintain equal width throughout the length; primary spines comprise of three thin blades with broad grooves and are triradiate in axial section.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of spines	254	276	198
Diameter of test	296	300	287

Material: 34 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232, 223, 220).

Remarks: This species differs from others by having very irregular pore frames.

?***Entactinosphaera*** sp. B

Pl. 25, figs. 2, 3.
Cat. Nos. 3054/6, 3251/8.

Description: Cortical shell spherical, moderate in size composed of a single layer of regular polygonal pore frames. Pores circular to subcircular. Primary spines long, straight, and maintain equal width throughout most of their length.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of spines	287	375	181
Diameter of test	287	299	280

Material: 8 specimens

Range: Upper Triassic (as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 223, 246, 231).

Remarks: This form differs from other members of the genus *Entacinosphaera* by having regular pores and pore frames.

Genus ***VEGHIA*** Kozur and Mostler, 1981.

Type species: Veghia goestlingensis Kozur and Mostler, 1981.

Origin description: (of Kozur and Mostler, 1981 p. 86) Grosser spharischer Cephalis ohne Apicalhorn. In der sonst unperforierten Wand liegen unregelmassig verstreut einzelne Poren. Die drei Fosse sind sehr lang, nach unten gerichtet und laufen distal zusammen, ohne sich zu berühren. Sie liegen in verlangerung von D und L. Sie besitzen sehr hohe Aussenkanten, die weit auf die Cephaliswand hochgreifen. Von den Seitenkanten der fosse geht ein kraftiger Randwulst aus, der um die gesamte Mundoffnung herumluft. Spicularsystem mit Mb, A, V, D, L und I. B gen in die Schalenwand eingebettet und kaum erkenbar.

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs from *Poulpus* De Wever, 1979 by having a distal vellum.
Veghia sulovensis Kozur and Mostler,1981.
Pl. 25, fig. 7.
Cat. No. 3100/17.

*1981 *Veghia sulovensis* Kozur and Mostler in Kozur and Mostler, p. 87, Pl. 31 fig. 1.

Original description: (of Kozur and Mostler, 1981 p. 87) Mit den Gattungsmerkmalen. Cephalis glatt mit einzelnen grossen Poren, sonst unperforiert. Aussenkante der Fosse hoch, aber nicht blattartig.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of spines	217	223	209
Diameter of test	97	101	95

Material: 4 specimens

Range: Upper Triassic (as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: Veghia sulovensis differs from other species of *Veghia* by having long distal arms.

Veghia sp. aff. ***V. goestlingensis*** Kozur and Mostler, 1981.
Pl. 25, figs. 4, 5.
Cat. Nos. 3100/9.

aff.*1981 *Veghia goestlingensis* Kozur and Mostler in Kozur and Mostler, p. 86, Pl. 30, fig. 1.

Original description: (of Kozur and Mostler, 1981 p. 86-87) Mit den

Gattungsmerkmalen. Cephalisporen vereinzelt und sehr klein. Aussenkante der Fosse sehr hoch, blattartig, distal am höchsten. Cephaliswand uneben, mit einzelnene undeutlichen Rippen.

Dimensions (microns):	Average of 5 specimens	max.	min.
Length of arms	206	210	202
Diameter of test	110	115	107

Material: 5 specimens

Range: Upper Triassic (Norian-Rhaetian as far as known).

Occurrence (literature): Europe.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220).

Remarks: This species differs from the holotype by having better developed meshwork on the cephalis, although this could be as a result of preservation.

Family **PSEUDODICTYOMITRIDAE** Pessagno, 1977

Type genus: Pseudictyomitra Pessagno, 1977.

Range: Upper Triassic to Upper Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Included genera (for this study): Corum Blome, 1984.

Remarks: The only genus within this family recovered during this is *Corum* Blome, 1984.

Genus ***CORUM*** Blome, 1984.

Type species: Corum speciosum Blome, 1984

Original description: (of Blome, 1984 p. 50) Test multicyrtid, conical. Cephalis dome-shaped, lacking horn; thorax subtrapezoidal in outline; cephalis and thorax imperforate, smooth or weakly developed, discontinuous costae. Abdomen and post-abdominal chambers subtrapezoidal in outline, slightly inflated and strongly costate, costae mostly discontinuous. One row of primary pores adjacent to distal end of costae; pores large, circular to elliptical in outline; final post-abdominal chamber perforate to imperforate. Chambers expanding in width and less rapidly in in height as added.

Range: Upper Triassic (upper Carnian? - middle Norian).

Occurrence (literature): Western North America.
Occurrence (this study): West Timor, Indonesia.

Remarks: Corum differs from *Pseudodictyomitra* Pessagno, 1977 by having only one row of primary pores situated between chambers and by lacking rows of large relict pore between the costae.

Corum sp. aff. ***C. perfectum*** Blome, 1984
Pl. 26, fig. 3.
Cat. No. 3073/31.

aff.*1984 *Corum perfectum* Blome in Blome, p. 51, Pl. 13, figs. 2, 7, 16, Pl. fig. 11.

Original description: (of Blome, 1984 p. 51) Test as for genus, consisting of six to seven post-abdominal chambers. Thorax subtrapezoidal in outline, smooth. Abdomen and post-abdominal chambers strongly costate; costae well-developed, discontinuous, moderately inflated, with about 28 to 30 costae (14 to 15 visible laterally). Pores at the distal end of costae small in size, circular to elliptical in outline. Final post-abdominal chamber imperforate, lacking well-developed costae on well-preserved specimens. Chambers increasing gradually in height and more rapidly in width as added, the exception being the final post-abdominal chamber, which decreases in width; width of any chamber approximately three times the height .

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of test	356	376	345
Diameter of test (widest)	113	121	105

Material: 4 specimens

Range: Upper Triassic (upper Carnian - middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: This form differs from the holotype of Blome (1984) by having more post-abdominal chambers (eight as opposed to 7).

Corum regium Blome, 1984.
Pl. 26, fig. 11.
Cat. No. 3026/31.

aff.*1984 *Corum regium* Blome in Blome, p. 51, Pl. 13, figs. 3, 6, 15.

Original description: (of Blome, 1984 p. 51) Test as for genus, consisting of five to six postabdominal chambers. Thorax trapezoidal in outline, smooth or weakly developed costae. Abdomen and postabdominal chambers strongly costate; costae course, discontinuos with 24 costae (12 visible laterally). Pores at distal end of costae large, circular to subcircular in outline. Final post-abdominal chamber imperforate, lacking costae on well-preserved specimens. Chambers increase gradually in height and more rapidly in width as added; the exception being the final post-abdominal chamber, which decreases in width; width in any chamber approximately three times the height .

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of test	219	224	215
Diameter of test (widest)	108	117	103

Material: 4 specimens

Range: Upper Triassic (Carnian to middle Norian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: C. regium differs from other species of *Corum* by having only five to six post-abdominal chambers.

NASSELLARIINA incertae sedis

Genus ***BIPEDIS*** De Wever, 1982.

Type species: Bipedis calvabovis De Wever, 1982.

Original description: (See De Wever, 1982 p. 192)

Remarks: De Wever (1982) introduced the genus *Bipedis* which was Early Jurassic in age. Kozur (1984) described the Middle Triassic genus *Triassobipedis*. Carter (1993) recovered two forms of a genus which contained features common to both *Triassibipedis* and *Bipedis* which is logical given the Rhaetian age between the two genera and so questions the assignment to *Bipedis* De Wever. This author would also question the assignment to *Bipedis* De Wever, because of the rarity of specimens and general poor preservation which makes investigation of the internal spicular system impossible.

Bipedis sp. A
Pl. 16, fig. 1, Pl. 23, figs. 1, 3
Cat. Nos. 3074/8, 3100/3, 3074/9.

Description: Dicyrtid test composed of a subtrapezoidal cephalis and thorax with a bladed apical horn. Thorax has two feet which are a similar shape to the apical horn and slightly larger in size. Feet are angled downwards and a small, circular opening in between.

Dimensions (microns):	Average of 8 specimens	max.	min.
Diameter of central test	119	125	114
Length of arms	120	122	118

Material: 11 specimens

Range: Upper Triassic (Norian and Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 220, 246, 223).

Remarks: Bipedis sp. A differs from *B. acrostylus* Bragin, 1991 by not having pores at the base of the bases of the feet, which may be a result of poor preservation.

Family **LIVARELLIDAE** Kozur and Mostler, 1981.

Type genus: Livarella Kozur and Mostler, 1981.

Original description: (of Kozur and Mostler, 1981 p. 114) Subspharische Schale mit dicht stehenden feinen Poren. Die drei in einer Ebene liegenden Arme weisen ebenfalls dicht stehende feine Poren auf. An den Armenden werden die Poren betrachtlich grosser. Innenmerkmale unbekannt.

Range: Upper Triassic (upper Norian and Rhaetian).

Occurrence (literature): Western North America, Europe, Middle East, Japan, China eastern USSR, Philippines and Oman.
Occurrence (this study): West Timor, Indonesia.

Remarks: Kozur and Mostler (1981) introduced this family leaving it with no affiliation as they could not be sure of the test origin. Yeh (1992) emended the interpretation of Kozur and Mostler believing that the Livarellidae were dicyrtid nassellarians with the node corresponding to the cephalis. The illustrations of Yeh (1992) do not fully show the internal structure of the node. Carter (1993) studied numerous specimens of *Livarella* from the Queen Charlotte Islands and found evidence of a spicular system in one individual. Furthermore, Yeh (1992) believed that the Livarellidae had three to six rays on the thorax. The six rayed forms appear to be examples of the Genus *Citraduma* De Wever, 1982. As yet, no well illustrated examples of the inner structure of the possible cephalis or node found in *Livarella* has been published therefore, the examples of Livarellidae will remain without affiliation.

Genus *LIVARELLA* Kozur and Mostler, 1981.

Type species: Livarella densiporata Kozur and Mostler, 1981.

Original description: (of Kozur and Mostler, 1981 p. 114-115) Subspharische Schale mit dicht stehenden feinen Poren. Die drei in einer Ebene liegenden Arme weisen ebenfalls dicht stehende feine Poren auf. An den Armenden werden die Poren betrachtlich grosser. Innenmerkmale unbekannt.

Range: Upper Triassic (upper Norian and Rhaetian).

Occurrence (literature): Western North America, Europe, Middle East, Japan, China eastern USSR, Philippines and Oman.
Occurrence (this study): West Timor, Indonesia.

Remarks: Carter (1993) reported that some taxa contained a pore on the side of the node. This pore has not been observed on specimens of *Livarella* recovered during this study, although, this may the result of preservation.

Livarella densiporata Kozur and Mostler, 1981.
Pl. 13, figs. 3, 4, 5, 6.
Cat. Nos. 3914/8, 3914/6, 3914/7, 3914/9.

*1981 *Livarella densiporata* Kozur and Mostler in Kozur and Mostler, p. 115, Pl. 9, fig. 1.
1986 *Livarella densiporata* Kozur and Mostler; Yoshida, p. Pl. 2, fig. 1-2.
1990 *Livarella densiporata* Kozur and Mostler; Carter, Pl. 1, fig. 3.
1992 *Livarella densiporata* Kozur and Mostler; Yeh, p. 67, Pl. 3, figs. 8, 11, Pl. 4 figs. 8, 11, 12, 15
1993 *Livarella densiporata* Kozur and Mostler; Carter, p. 116, Pl. 21, figs. 1, 5, 10, 13, 16.

Original description: (of Kozur and Mostler, 1981 p. 114-115) Die Oberflache der subspharischen Schale ist dicht mit sehr kleinen runden Poren besetzt. Die gleiche Wandstruktur findet sich auch auf den drei kraftigen runden Armen. Nur distal sind die Poren auf den Armen deutlich vergrossert. Die Arme haben auf ihrer gesamten Lange den gleichen Durchmesser oder sie sind proximal geringfugig eingeschnurt. Die Armenden sind gerundet.

Dimensions (microns):	Average of 10 specimens	max.	min.
Length of arms	88	95	79
Width of arms (at base)	49	53	46
Diameter of central test	112	117	108

Material: 10 specimens

Range: Upper Triassic (upper Norian and Rhaetian).

Occurrence (literature): Queen Charlotte Islands, Japan, Europe, Philippines.
Occurrence (this study): Noil Meto, Soe West Timor, Indonesia (Sample 220, Tr 90 009s).

Remarks: As with Carter, 1993 all specimens of this species possess a node. *L. densiporata* differs from other species of *Livarella* by having a globular test with short, wide rays.

Livarella sp. aff. ***L. gifuensis*** Yoshida, 1986.
Lost
Cat. Nos. 3221/23

aff.* 1986 *Livarella gifuensis* Yoshida in Yoshida, Pl. 2, figs. 6-10.
aff.1993 *Livarella* sp. aff, *L. gifuensis* Yoshida; Carter, 1993, Pl. 21, figs. 8, 9.

Original description: (of Yoshida, 1986 p. 15) Shell spherical with small pore frames. Cortical shell spherical in shape. Internal shell structure unknown. Length of arm approximately one and a half times longer than the size of cortical shell.

Dimensions (microns):	Average of 8 specimens	max.	min.
Length of arms	129	132	118
Width of arms (at base)	55	62	48
Diameter of central test	97	102	89

Material: 8 specimens

Range: Upper Triassic (upper Norian and Rhaetian).

Occurrence (literature): Queen Charlotte Islands, Japan, Europe, Philippines.
Occurrence (this study): Noil Meto, Soe West Timor, Indonesia (Sample 220).

Remarks: Livarella sp. aff. *L. gifuensis* differs from *L. densiporata* by having longer, more slender rays.

Livarella sp. A
Pl. 13, fig. 7.
Cat. No. 3608/19.

Description: Test moderate size with three equally spaced, curved and tapering rays. Test wall comprised of fine microgranular silica. Rays and central part of the test not distinctly separated.

Dimensions (microns):	Average of 6 specimens	max.	min.
Length of arms	121	135	114
Width of arms (at base)	53	58	48
Diameter of central test	83	95	76

Material: 6 specimens

Range: Upper Triassic (Norian/Rhaetian).

Occurrence (this study): Noil Meto, Soe West Timor, Indonesia (Sample Tr 90 021S).

Remarks: Livarella sp. A differs from *L. validus* by having continuously tapering rays.

Genus ***POULPUS*** De Wever, 1979.

Type species: Poulpus piabyx De Wever, 1979.

Original definition: (of De Wever, 1979 p. 94) Spyroid-like radiolarians with hemispherical cephalis including three (AV and and two al), 6 normal collar pores, and 3 well-developed feet.

Range: Upper Triassic

Occurrence (literature): Europe, North America.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs from *Saitoum* by lacking arches in the cephalic wall.

Poulpus piabyx De Wever, 1979
Pl. 12, Figs. 11, 12.
Cat. No. 3057/12

Original description: (of De Wever, 1979 p. 98) Test subhemispherical (slightly flatened) with 3 downwardly curved feet. The hemispherical part, without horn, has a lumpy surface and small rounded pores in polygonal frames. The circular mouth is smooth, without lobes. The 3 feet are rounded apparently hollow tubes, downwardly directed, proximally only slightly, and distally more pronouncedly.

Well-developed cephalic elements are visible at the base of the hemisphere. Six collar pores are present separated by bars evidently homologous with those well known in Cenozoic nassellarians - median bar, vertical, dorsal and primary and secondary laterals. From the median bar, near the origin of the secondary laterals, arises an apical bar which passes freely through the cephalic cavity to join the shell wall. At the terminus of the apical bar arises 3 arches which run in the shell wall to join the vertical bar and 2 secondary lateral bars.

Range: Upper Triassic.

Material: 4 specimens.

Occurrence (literature): Europe, Japan, North America.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 223, 115).

Remarks: This species is differentiated from other forms of *Poulpus* by having a flatter cephalis, rounded feet and a smooth peristome.

Nassellarian gen. indet. and sp. indet. A
Pl. 26, figs. 9, 10.
Cat. Nos. 3073/14, 3073/34.

Description: Test spindle-shaped, inflated medially and constricted distally. Cephalis imperforate with a massive, long apical horn. Test wall thick with massive irregular meshwork.

Dimensions (microns):	Average of 3 specimens	max.	min.
Length of test	285	310	272
Diameter of test (widest)	152	175	97

Material: 3 specimens
Range: Upper Triassic (Norian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 246).

Remarks: This taxon is similar to forms of the genus *Canutus* as reported in Carter (1993), however, the preservation is not good enough to identify these forms accurately.

Nassellarian gen. indet and sp. indet. B
Pl. 26, fig. 4.
Cat. No. 3057/1.

Description: Test gradually increases in diameter with final chambers decreasing. Cephalis conical, imperforate with a stout apical horn. Thorax and abdomen perforated by small circular pores; thorax and abdomen subtrapezoidal in outline. Test with strong longitudinal costae which remain the same thickness over their entire length.

Dimensions (microns):	Average of 4 specimens	max.	min.
Length of test	221	245	198
Diameter of test(widest)	95	106	87

Material: 4 specimens

Range: Upper Triassic (lower Norian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 232).

Remarks: This species is superficially similar to the Jurassic genus *Thanarla*, however, the lack of well-preserved specimens does not allow an accurate assignment of this form.

Genus *PSEUDOLIVARELLA* n. gen.

Type species: Pseudolivarella barkhami n. sp.

1993 Nassellaria gen. and sp. indet. A Carter, p. 115, Pl. 20, figs. 7, 8.

Diagnosis: Test tricyrtid with apical horn; overall test shape pear to bottle-shaped with two strong cylindrical distally pointing arms situated on the abdomen.
Desription: Test tricyrtid, pear to bottle-shaped with an apical horn; apical horn varies from small and circular in axial section to large, stout and arrow-shaped. Cephalis small hemispherical to elongate, thorax trapezoidal in outline, abdomen inflated becoming constricted distally with a prominent distal apperture. Two large, distally pointing arms of equal length occur on abdomen; abdomen arms are circular to elliptical in axial section. Test walls thick with a coarse, spongy meshwork.

Range: Upper Triassic (upper Norian-Rhaetian)

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): West Timor, Indonesia.

Etymology: This species is named pseudo- (Greek=false) and livarella for its resemblance to the genus *Livarella* Kozur and Mostler, 1981.

Type locality: River Meto Sections, West Timor, Sample 223, 231, 223 (see Chapter 4 section logs).

Remarks: This genus is first reported by Carter (1993, p. 115, Pl. 20, figs. 7, 8) as Nassellaria gen. and sp. indet. B and is thought by Carter (1993) to be related to Nassellaria gen. and sp. indet. A, Carter, 1993 p. 115, Pl. 20, figs. 9, 14. The fact that this distinctive genus occurs in N. America and in Indonesia and is restricted to the upper Norian and Rhaetian of both regions gives it an importance biostratigraphically. The specimens found in Indonesia are not as well-preserved as those from the Queen Charlotte islands and have a longer cephalic horn these features combine to give a close resemblance to the genus *Livarella*.

Pseudolivarella barkhami n. sp.
Pl. 13, figs. 8, 9.
Cat. No. 3608/12, 3608/13

Diagnosis: Test bottle-shaped with long tubular cephalis and small apical horn. Abdominal arms slighty larger than cephalis and thorax.

Description: Test tricyrtid with small nipple-like apical horn. Cephalis elongate and tubular; thorax trapezoidal in outline and inflated; abdomen inflated, circular in outline becoming constricted distally with a priminent distal opening. Abdominal arms large, stout, circular in axial section and slightly larger than the cephalis and thorax.

Dimensions (microns):	Average of 9 specimens	max.	min.	Holotype
Length of test	283	291	272	284
Width of test (widest) - across abdomen	167	175	159	164

Material: 6 specimens

Range: Upper Triassic (upper Norian-Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample 224, 213, 231, Tr 90 036, Tr 90 035, Tr 90 021, Tr 90 020).

Etymology: This species is named for Dr. S. T. Barkham for his work on the geology of the Mesozoic sediments of West Timor, Indonesia.

Type locality: River Meto Sections, West Timor, Sample 223, 231, 223 (see Chapter 4 section logs).

Remarks: This form differs from Nassellaria gen. and sp. indet B, Carter (1993, p. 115, Pl. 20, figs. 7, 8) by having longer abdominal arms and by having a small apical horn and is confined to the upper Norian-Rhaetian of Timor and the Queen Charlotte Islands. This species is similar to *Livarella* on initial inspection.

Nassellarians marked LOST or NOT ILLUSTRATED

Xiphotheca sp aff. ***X. karpenissionensis*** De Wever, 1979
Not illustrated
Cat. No.

aff.*1979 *Xiphotheca karpenissionensis* De Wever in De Wever *et al.* p. 93, Pl. 7 figs. 1-5

Original description: (of De Wever *et al.*, 1979 p. 93) A delicate, elongate form, never observed entire: Cephalis small, more or less conical without distinct pores. Second segment larger than the first, convex-annular, with indistinct pores. Third segment wider than remainder of skeleton. In some specimens this bears tiny thorns. Pores on third segment are clearly visible, and in some specimens these are arranged in longitudinal rows. Its length is double that of the cephalis.

The central part of the skeleton is the longest, tubular without spines. Its pores are commonly aligned longitudinally and in some specimens transversly as well. The proximal part shows two gentle constrictions. Towards the distal extremity the tube becomes constricted in successively shorter wavelengths producing 3 or 4 undulations on the wider part of which the pores are commonly arranged in 2 transverse rows. The narrower parts of the undulations are poreless. The terminal aperture is flared and thorny.

Material: 8 specimens

Range: Upper Triassic

Occurrence (literature): Worldwide
Occurrence (this study): Noil Meto, Soe, W. Timor, Indonesia (Sample Tr 90 049s, Tr 90 056s)

Remarks: This species is distinctive because it is nearly always incomplete as described by De Wever *et al.* (1979)

Genus *GLOBOLAXTORUM* Carter, 1993

Type species: Globolaxtorum tozeri Carter, 1993

Original description: (of Carter, 1993 p. 110) Test multicyrtid, spindle-shaped, consisting of more than five post abdominal chambers; chambers gradually expand, become quite inflated, then constrict to form a terminal tube. Cephalis with apical horn. Thorax, abdomen and first few post abdominal chambers closely spaced, subtrapezoidal in outline, gradually increase in width as added. Succeeding chambers inflated in both width and height; final chambers becoming constricted, reduced in height and leading to elongate terminal tube. Test consisting of two layers of irregular pore frames; inner layer lacking nodes, outer layer with quite massive nodes. Outer layer confined primarily to to circumferential ridges. Terminal tube open, composed of a single layer of pore frames. Short medial spines extend radially from inflated area of test.

Range: Upper Triassic (Rhaetian).

Occurrence (literature): Queen Charlotte Islands, Philippines, Oman.
Occurrence (this study): West Timor, Indonesia.

Remarks: Globolaxtorum evolved from *Laxtorum* Blome emend. Carter, 1993 and differs by having an inflated medial post abdominal area. *Globolaxtorum* also differs from *Katroma, Pleesus* and *Syringocapsa* by having a two layered test wall.

Globolaxtorum sp. aff. ***G. tozeri*** Carter, 1993.
Not illustrated
Cat. No. 3221/5

aff.* 1993 *Globolaxtorum tozeri* Carter, p. 110, Pl. 19, figs. 14, 15, 16, 18, 19.

Original description: (of Carter, 1993 p. 111) Test as with genus, usually with five post abdominal chambers and long terminal tube. Cephalis conical, imperforate with long robust apical horn. Thorax, abdomen and first two post abdominal chambers closely spaced, conical in overall outline; width of chambers gradually increasing, height almost constant. Circumferential ridges low in relief, rounded; one or two rows of pores per ridge. Third chamber becoming more expanded; fourth chamber highly inflated, forming maximum expansion of test, width about twice that of height; final chamber again constricted and reduced in height. Outer layer of pore frames small on initial chambers, confined mostly to circumferential ridges. Pore frames larger and very irregular on inflated chambers.; walls deep with small, pointed nodes at vertices of bars. Terminal tube long and tapering, composed of a single layer of relatively large, square to rectangular pore frames. Well-preserved specimens have several, short, downward sloping thorns at tip of tube. Test usually with six or seven very short, slender, radially arranged medial spines on inflated chamber.

Material: 2 specimens

Range: Upper Triassic (Rhaetian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 023, Tr 90 035).

Remarks: Generally *Globolaxtorum tozeri* is larger than other species within this genus.

Genus ***PARAHSUUM*** Yao, 1982

Parashuum? sp. A
Not illustrated
Cat. No. Tr 90 007s/1

*1987 *Parahsuum* (?) sp. A Kojima and Mizutani in Kojima and Mizutani p. 260-261, Pl. 2 (=fig. 3), figs. 10

Original description: (of Kojima and Mizutani, 1987 p. 260-261) Test conical and cylindrical distally. Cephalis trapezoidal, poreless, without apical horn. Proximal one-third to one-fifth of test poreless, the rest covered by irregular pored meshwork.

Range: Upper Triassic (Rhaetian)

Material: 12 specimens

Occurrence (literature): China.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 007s,

224)

Remarks: This species appears to be very important biostratigraphically and occurs only in the Rhaetian with forms of ?*Eucyrtidellium* and *Pseudolivarella* n. gen. in this study.

Other RARE Nassellarians NOT ILLUSTRATED

?***Eucyrtidellium*** sp. A
?***Eucyrtidellium*** sp. B
Yeharaia japonica Nakeseko and Nishimura, 1979.
Tricolocapsa sp. A
?***Plafkerium*** sp. A

Appendix 2

A.2.1.0 Sytematic Palaeontology of Lower Jurassic Radiolarians

A.2.1.1 Introduction

This chapter presents the taxonomy of the Radiolarians from Aitutu and Wai Lull formations of Timor, eastern Indonesia. Limestones form the majority of the sample lithologies, although some shales and marls have yielded excellent assemblages of Late Triassic and Early Jurassic age. The classification of polycystine radiolarians of Riedel (1967b, 1971) forms the basis for this study. Important additions to this have been made by Baumgartner (1980), Carter (1988), De Wever (1981a, 1984), Pessagno (1973, 1976, 1977) Pessagno, Whalen (1982) and Yeh (1986) and Yeh (1987) and the work of these authors is used extensively.

The Lower Jurassic radiolarians described in this chapter are separated from the abundant Upper Triassic radiolarians recovered during this study because the sections and/or sampling is incomplete between the two assemblages, preservational differences occur suggesting a geographical or diagenetic separation (Lower Jurassic forms are generally less well-preserved and are usually replaced by calcite, whereas the Upper Triassic specimens consist of silica) and the diversity is greatly reduced in the Lower Jurassic (which may reflect general faunal turn over, palaeonenvironmental stress or preservational problems).

At a generic level, the Upper Triassic and Lower Jurassic assemblages vary greatly with only *Canoptum, Crucella, Paronaella, Pantanellium* and *Orbiculiforma* occurring in both suites of samples. All of the exotic and rapidly radiating groups observed in the Upper Triassic sediments are extinct or not preserved in the Lower Jurassic sampled herein. The absence of delicate taxa such as the saturnalids is possibly the result of diagenesis, however, the most noteable difference between the two overall assemblages is the increase in Nassellarians observed in the younger sediments. This appears to be a reflection of the genuine change in the ratio of Spumellarians to Nassellarians and is probably reinforced by the lack of preservation of delicate taxa.

The absence of section or samples is shown in the lithological logs in Chapter 4 together with a range chart of taxa recovered in the Early Jurassic sediments of Timor.

A.2.2.0 Systematics notes:

1) *= designated type species
2) Noil=Indonesian for river
3) specimens marked "lost" were broken during preparation for the SEM
4) Catalogue Numbers for each specimen refer to photographic film and frame numbers (e.g. Film 3020/ frame number 15). Illustrations of the same specimen for close-ups or at different angles bear the same catalogue number, with a different figure number.
6) Specimens marked "not illustrated" are given a catalogue number which represents a sample number in which they are found.
7) Within this systematic section, "*Range:* " refers to the range given by the author who designated the species originally, or when a more recently published range is known. The terms upper or late and their uses are explained in Chapter 5 which is concerned with general problems encountered in this study. "*Range:*" generally refers to information gained from the literature, where a new species is described "*Range:*" is the range of the species believed to apply within the sediments studied herein.
8) Specimens with figure numbers in **bold** on the plate explanations are important biostratigraphically to this study.

Phylum **PROTOZOA**
Subclass **RADIOLARIA** Muller, 1858
Order **POLYCYSTINA** Ehrenberg, 1838
emend. Riedel, 1967
Suborder **SPUMELLARIA** Ehrenberg, 1875

Genus *ARCHAEOCENOSPHAERA* Pessagno *et al.*, 1989.

Type species: Archaeocenosphaera ruesti Pessagno *et al.*, 1989.

Range: Palaeozoic?; Triassic to Cretaceous (as far as known).

Occurrence (literature): Tethyan and Boreal Realms.
Occurrence (this study): West Timor, Indonesia.

Remarks: Archaeocenosphaera differs from *Cenosphaera* Ehrenberg by having a thick cortical shell with two fused latticed layers and by usually having symmetrical polygonal pore frames. *Archaeocenosphaera* differs from *Triactoma* by lacking three secondary spines.

Archaeocenosphaera? sp. A
Pl. 27, fig. 4.
Cat. No. 3908/2

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 017.1s).

Material: 1 specimen

Remarks: This species is characterised by large, regular, hexagonal pore frames with nodes at the pore frame vertices.

Genus *BISTARKUM* Yeh, 1987.

*Type species: **Bistarkum rigidum*** Yeh, 1987.

Range: Lower Jurassic (upper Pliensbachian to lower Toarcian)

Occurrence (literature): Europe, Western North America.
Occurrence (this study): W. Timor, Indonesia.

Remarks: Yeh (1987) introduced the name *Bistarkum* to avoid assigning species to *Amphibrachium*, which has a poor illustration and description of its type species. Other publications tend to exhibit poor specimens (Baumgartner, 1980). Specimens recovered in this study exhibited other variations such as torsion of the ray tips and a groove along the sides of the arms. *Bistarkum* was chosen as the genus for this morphotype because the descriptions for *Amphibrachium* tended to poor and did not include the morphological variations observed in this study.

Bistarkum regidium Yeh, 1987.
Pl. 27, figs. 1, 2.
Cat. Nos. 3608/22, 3909/33.

*1987 *Bistarkum regidium* Yeh, p. 43-44, Pl. 1, fig. 5, Pl. 21, fig. 5, Pl. 22, figs. 1, 3, 7, 11.

Range: Lower Jurassic (upper Pliensbachian to lower Toarcian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 009s, Tr 90 010s, Tr 90 019, Tr 90 038s).

Material: 7 specimens

Remarks: B. regidium differs from *B. bifurcum* Yeh, 1987 by lacking bifurcate tips and by having a wider test.

Genus ***CRUCELLA*** Pessagno, 1971 **emend.** Baumgartner, 1980.

Type species: Crucella messinae Pessagno, 1971.

Range: Palaeozoic to Upper Crteaceous

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: This has a similar internal canal structure to *Paronaella.*

***Crucella*?** sp. A
Pl. 27, fig. 11.
Cat. No. 3909/24.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 003s, Tr 90 004s, Tr 90 009s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 016s, Tr 90 017.2s, Tr 90 019s, Tr 90 025s, Tr 90 039s).

Remarks: This species has a raised central area.

***Crucella*?** sp. B
Not illustrated
Cat. No. 3221/20.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (SampleTr 90 009s).

Remarks: This species is generally poorly preserved with straight, moderately long rays.

Genus *ORBICULIFORMA* Pessagno, 1973

Type species: Orbiculiforma quadtrata Pessagno, 1973.

Range: Lower Triassic-Lower Cretaceous

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Orbiculiforma differs from other Mesozoic spumellarians by having a disc-shaped spongy test with a concentric arrangement throughout and central cavities on either side of the test (Blome, 1988).

Orbiculiforma callosa Yeh, 1987.
Pl. 29, Fig. 13.
Cat. No. 3908/14.

*1987 *Orbiculiforma callosa* Yeh, p. 41, Pl. 2, fig. 25, Pl. 5, fig. 19, Pl. 11, fig. 7, Pl. 22, figs. 10, 11.

Range: Lower Jurassic (upper Pliensbachian-lower Toarcian).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia, (Sample Tr 90 001s, Tr 90 002s, Tr 90 003s, Tr 90 004s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 018s, Tr 90 019s, Tr 90 025s, Tr 90 033s, Tr 90 039s, Tr 90 040s).

Remarks: This species is found in many of the Lower jurassic samples recovered from Timor.

?***Orbiculiforma*** sp. A
Not illustrated
Cat. No. 90 002/1.

Range: Lower Jurassic (upper Pliensbachian-lower Toarcian).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s,

Tr 90 003s, Tr 90 010s, Tr 90 019s, Tr 90 038s).

Remarks: This species is tentatively placed in the genus *Orbiculiforma* as it has a lip around the inner part of the rim.

Genus ***PARONAELLA*** Pessagno, 1971 **emend**. Baumgartner, 1980.

*1971 Paronaella Pessagno, p. 46.
1971 Patulibracchium Pessagno, p. 26.
1978 Pessagnobracchia Kozur and Mostler, p. 142.
1980 Paronaella pessagno, **emend**. Baumgartner, p. 300.
1980 Patulibracchium Pessagno, Baumgartner, p. 308.
1981a Paronaella Pessagno, Lower. De Wever, p. 33.

Type species: Paronaella salonoensis Pessagno, 1971.

Range: Lower Palaeozoic? to Lower Cretaceous.

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Baumgartner (1980) included forms with bulbous or expanded ray tips within this genus, whereas Pessagno's original diagnosis did not. De Wever (1982) noted that the definition of this genus had evolved from Pessagno's original definition (1971) based entirely on external features to Baumgartner's work (1980) when it was recognised that the internal structures were decisive for correct identification of this genus. The bracchiopyle, as reported by De Wever (1981a) may or may not be present in this genus, thus its significance as a diagnositic feature is reduced.

Paronaella grahamensis Carter, 1988.
Pl. 27, fig. 6.
Cat. No. 3608/28.

Range: Lower-Middle Jurassic (middle Toarcian to Aalenian).

Occurrence (literature): Queen Charlotte Islands, British columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 025s,

Tr 90 001s, Tr 90 002s, Tr 90 003s, Tr 90 004s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 018s, Tr 90 019s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s).

Remarks: This species is long ranging and commonly found in samples recovered from Timor.

Paronaella sp. B
Not illustrated
Cat. No. 90 002/2

Range: Lower Jurassic

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s, Tr 90 004s, Tr 90 018s)

Remarks: This species of *Paronaella* has curved rays.

Paronaella sp. C
Not illustrated
Cat. No. 90 010/2

Range: Lower Jurassic

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 018s, Tr 90 038s).

Remarks: This species of *Paronaella* has short, stout, rotund rays.

Paronaella sp. D
Not illustrated
Cat. No. 90 009/1

Range: Lower Jurassic

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 009s, Tr 90 012s, Tr 90 039s)

Remarks: This species of *Paronaella* has spiney rays.

Genus *PRAECONOCARYOMMA* Pessagno, 1976

Type species: Praeconocaryomma universa Pessagno, 1976 p. 42, Pl. 6, figs. 14-16.

Range: Lower Jurassic (upper Pliensbachian) to Lower Cretaceous (middle Campanian).

Occurrence (literature): Worldwide Tethyan and Boreal Realms.
Occurrence (this study): West Timor, Indonesia.

Remarks: Pessagno (1976, p. 41) noted that the genus is distinguished from *Conocaryomma* Lipman (Known from the Eocene) by the number of medullary shells (three in *Praeconocaryomma* and four or five in *Conocaryomma*).

Praeconocaryomma immodica Pessagno and Poisson, 1981.
Not illustrated
Cat. No. 90 009/3

*1981 *Praeconocaryomma immodica* Pessagno and Poisson, p. 57, Pl. 7, figs. 2-9.
1988 *Praeconocaryomma immodica* Pessagno and Poison; Carter, 1993, p. 31, Pl. 1 fig. 1.

Range: Lower Jurassic (late Pliensbachian to late Toarcian).

Occurrence (literature): Europe, N. America.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 009s).

Remarks: This species has the relatively short range of upper Pliensbachian to upper Toarcian according to Carter (1988).

Praeconocaryomma parvimamma Pessagno and Poisson, 1981.
Not illustrated
Cat. No. 90 003/5

*1981 *Praeconocaryomma parvimamma* Pessagno and Poisson, p 58, Pl. 8, figs. 5-8, Pl 9, fig. 2)

Range: Early Jurassic, Sinemurian-Pliensbachian.

Occurrence (literature): Turkey, N. America.
Occurence (this study): Noil Meto, West Timor, Indonesia (Sample Tr 90 003s, Tr 90 009s, Tr 90 038s).

Remarks: This species differs from *Praeconocaryomma media* Pessagno and Poisson, 1981, by having much smaller mammary pore frames.

Praeconocaryomma sp. A
Pl. 27, fig. 9.
Cat. No. 3909/19.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 017.2s, Tr 90 025s, Tr 90 001s, Tr 90 002s, Tr 90 009s, Tr 90 017s, Tr 90 017.1s, Tr 90 018s, Tr 90 038s)

Remarks: This species differs from others described herein by having large and regular mammae.

Praeconocaryomma sp. B.
Pl. 27, figs. 7, 8.
Cat. Nos. 3908/3, 3909/12.

Range: Early Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 001s, Tr 90 003s, Tr 90 004s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s).

Remarks: This species differs from others by having small, irregular mammae.

Genus ***PSEUDOAULOPHACUS*** Pessagno, 1963.

Type species: Pseudoaulophacus floresensis Pessagno, 1963.

Range: ? Lower Jurassic-Cretaceous

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: The assignment of this genus is questionable here as it is generally poorly preserved and in this study occurs in sediments much older than usual (Cretaceous, see Pessagno (1972)). It is entirely possible that these taxa form an ancestral group and belong to a different genus.

?***Pseudoaulophacus*** sp. A
Pl. 27 fig. 10.
Cat. No. 3221/22

Range: Lower Jurassic (Pliensbachian-Toarcian) as far as known

Occurrence (this study): Noil Meto, West Timor, Indonesia (Sample Tr 90 002s, Tr 90 003s, Tr 90 009s, Tr 90 010s, Tr 90 012s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s).

Remarks: Specimens usually consist of calcite and are therefore poorly preserved, however, show the basic almost foram-like shape of a flattened sphere with flattened bulges either side of the equatorial plane. The distinctly triangular meshwork

Genus ***SPONGOSTAURUS*** Haeckel, 1882.

Type species: Spongostaurus cruciatus Haeckel, 1887.

Range: Early Jurassic.

Occurrence (literature): Europe, N. America.
Occurrence (this study): West Timor, Indonesia.

Remarks: Carter (1988) assigned this genus to the Orbiculiformidae.

Spongostaurus sp. aff. ***S. cruciformis*** Carter, 1988.
Not illustrated
Cat. No. 90 009/4

aff.*1988 *Spongostaurus cruciformis* Carter, p. 45, Pl. 10, fig. 11.

Range: Lower Jurassic (middle-upper Toarcian).

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurence (this Study): Noil Meto, West Timor, Indonesia (Sample Tr 90 009s, Tr 90 016s, Tr 90 018s).

Remarks: This species differs fron *Staurospongus puguinculus* Carter, 1993 by having a more flattened test.

Genus ***TETRATRABS*** Baumgartner, 1980.

Type species: Tetratrabs gratiosa Baumgartner, 1980.

Range: Lower-Upper Jurassic (upper Toarcian-upper Tithonian).

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus differs from *Pseudocrucella* by havingregular double pore rows instead of irregular single pore rows.

?***Tetratrabs*** sp. A
Pl. 27, fig. 3.
Cat. No. 3914/2.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s, Tr 90 009s, Tr 90 010s).

Remarks: This form is generally poorly preserved and so is not easily assigned.

Suborder **NASSELLARIINA**

Genus ***CANOPTUM*** Pessagno 1979

Type species: Canoptum poissoni: Pessagno, 1979

Range: Upper Triassic (Carnian?-Norian) to Lower Jurassic (Toarcian).

Occurrence (literature): World-wide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Canoptum differs from *Spongocapsulum* Pessagno in having a two-layered test wall lacking spongy meshwork. It differs from *Parvicingula* Pessagno in possessing a two-layered test with a microgranular outer layer lacking discrete pore frames.

Canoptum anulatum Pessagno and Poisson, 1981.
Pl. 28, figs. 1, 2, 3.
Cat. Nos. 3909/22, 3908/7, 3909/32.

aff.*1981, *Canoptum anulatum* Pessagno and Poisson, p. 60-61, Pl. 9, figs. 6-9, Pl. 10, figs. 1-9, Pl. 15, figs. 2, 4.
1982, *Canoptum anulatum,* Pessagno and Whalen, Pl. 6, figs. 1, 2.
1987, Not *Paracanoptum anulatum,* Yeh,Pl. 4, fig. 28; Pl. 15, fig. 4; Pl. 27, figs. 1,9,11.

Range: Lower Jurassic (upper Sinemurian-Pliensbachian).

Occurrence (literature): Western North America, Turkey.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 025s, Tr 90 001s, Tr 90 002s, Tr 90 003s, Tr 90 004s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 039s, Tr 90 040s, Tr 90 006s)

Remarks: Differs from other species of *Canoptum* by having raised circumferential ridges with an H-link pattern and by having up to 20 chambers.

Genus ***CANUTUS*** Pessagno and Whalen, 1982

Type species: Canutus tipperi Pessagno and Whalen, 1982

Range: Lower Jurassic-Pliensbachian-Toarcian

Occurrence (literature): N. America, Japan.
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus is distinguished by having rods at the pore frame vertices.

?***Canutus gigantus*** Pessagno and Whalen, 1982
Not illustrated
Cat. No. 90 002/3

*?1982 *Canutus gigantus* Pessagno and Whalen in Pessagno and Whalen, p. 127, Pl. 4, figs. 5, 13.

Range: upper Pliensbachian

Occurrence (literature): N. America
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s, Tr 90 040s)

Remarks: This species is only rarely found in this study.

Canutus sp. A
Not illustrated
Cat. No. 90 033/1

Range: Lower Jurassic

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 033s, Tr 90 039s)

Remarks: This species is identical to *Canutus* sp. 11167 of Hattori and Sakamoto (1991) Pl. 13, fig. A.

Genus ***HSUUM*** Pessagno, 1977

Type species: Hsuum cuestaense Pessagno, 1977.

Range: Lower Jurassic (lower Pliensbachian) to Lower Cretaceous (upper Valanginian)

Occurrence (literature): Worldwide.
Occurrence (this study): West Timor, Indonesia.

Remarks: Pessagno and Whalen (1982 p. 130) believed that the test construction and the insertion of the costae were critical in the definition of this family.

?***Hsuum*** sp. aff. ***H. mirabundum*** Pessagno and Whalen, 1982.
Not illustrated
Cat. No. 90 003/4

* aff.1982 *Hsuum mirabundum* Pessagno and Whalen in Pessagno and Whalen, p. 131, Pl. 7, figs. 9, 17, 21.

Range (of type species): Middle Jurassic

Occurrence (literature): N. America.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 003s, Tr 90 017s, Tr 90 017.2s, Tr 90 033s)

Remarks: The type species is younger than the form occurring in this study and differs by having less well-developed costae.

Genus ***KATROMA*** Pessagno and Poisson, 1981 **emend.** De Wever, 1982

Type species: Katroma neagui Pessagno and Poisson, 1981

Range: Lower Jurassic (Sinemurian-lower Toarcian)
Occurrence (literature): Worldwide
Occurrence (this study): West Timor, Indonesia

Remarks: This genus is distinguished by being multicyrtid with the final post abdominal chamber being inflated and terminating in an open tubular extension

Katroma ninstintsi Carter, 1988
Not illustrated
Cat. No. 90 002/6

*1988 *Katroma ninstintsi* Carter in Carter p. 60, Pl. 2, figs. 4, 9.

Range: Lower Jurassic (upper Pliensbachian)

Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s).

Remarks: This species is believed to exhibit a number of variations.

?***Katroma*** sp. A
Not illustrated
Cat. No. 90 025/1

Range: Lower Jurassic (Pliensbachian-Toarcian)

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 025s, Tr 90 0003s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 033s, Tr 90 038s, Tr 90 039s)

Remarks: This species is poorly preserved and therefore is tentatively assigned to *Katroma.*

Genus *MAUDIA* Carter, 1988.

Type species: Maudia yakounense Carter, 1993.

Range: Lower Jurassic.
Occurrence (literature): Queen Charlotte Islands, British Columbia.
Occurrence (this study): West Timor, Indonesia.

Remarks: Carter (1993) did not examine the internal structure of this genus. *Maudia* differs from *Spongocapsula* by possessing an apical horn and laks septal partitions.

?***Maudia*** sp. A
Pl. 29, figs. 2, 3.
Cat. Nos. 3914/11, 3909/29.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s, Tr 90 004s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s).

Remarks: This form does not have a conical test (slightly medially constricted) as observed in the type species, also the internal structure is not known as all specimens are infilled with calcite.

?***Maudia*** sp. B
Pl. 29, fig. 4.
Cat. No. 3909/16.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 003s, Tr 90 009s, Tr 90 038s, Tr 90 039s).

Remarks: This form is characterised by an extremely large test (>600 microns) and the severe medial constriction which gives a bell-shaped outline to specimens.

Genus ***PERISPYRIDIUM*** Dumitrica, 1978.

Type species: Perispyridium ordinairia Pessagno, 1977

Range: Lower Jurassic (Toarcian) to Upper Jurassic (Tithonian).
Occurrence (literature): Romania, Greece, Italy, Switzerland, Western North America.
Occurrence (this study): West Timor, Indonesia.

Remarks: Perispyridium contains relatively advanced spumellarian features, appearing to have a microsphere and a peripheral latticed shell. This genus is the last survivor of the family exsisting entirely within the Jurassic. Macloed (1988) carried out extensive research on this particular genus and in the light of this defined two more important morphological features relavent to *Perispyridium.* The first new feature to be used in addition to the characters described by Dumitrica (1978) is the peripheral shell shoulders which are the lateral extensions surrounding the bases of the apical and primary lateral spines. These occur in two forms; simple and extended. The second feature is spine tip morphology, whether the spine tip has a crown-like appearance or not.

?***Perispyridium*** sp. A
Pl. 27, fig. 5.
Cat. No. 3908/25.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 010s).

Remarks: This species differs from others within this genus by having small and irregular polygonal pore frames throughout the peripheral shell and cephalis.

Genus ***PSEUDORISTOLA*** Yeh, 1987

Type species: Pseudoristola facetus Yeh, 1987

Range: Early Jurassic (lower Toarcian as far as known).

Occurrenc: (literature): Oregon.
Occurrence (this study): West Timor, Indonesia.

Remarks: Pseudoristola differs from *Ristola* Pessagno and Whalen, 1982 by having a test with pore frames more irregular in shape, by lacking well-developed circumferential ridges on postabdominal chambers, and by having its final postabdominal chamber closing with a large latticed bulbous expansion ratther than terminating in an open tublar extension.

Pseudoristola ***obesa*** Yeh, 1987
Pl. 28, figs. 13, 14, Pl. 29, fig. 5.
Cat. No. 3908/28, 3908/31.

*1987 *Pseudoristola obesa* Yeh, p. 96-97, Pl. 14, figs. 11-12.

Range: Lower Jurassic (lower Toarcian as far as known).

Occurrence (literature): Oregon,
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 009s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 038s, Tr 90 039s).

Remarks: Pseudoristola obesa by having an extremely short test with a very large bulbous subspherical final postabdominal chamber.

Pseudoristola sp. aff. ***P. megalobosa*** Yeh, 1987
Pl. 29, figs. 7, 8.
Cat. Nos. 3909/25, 3909/23.

*1987 *Pseudoristola megalobosa* Yeh, p. 96, Pl. 14, fig. 13, Pl. 23 figs. 17, 22.

Range: Lower Jurassic (lower Toarcian as far as known).

Occurrence (literature): Oregon.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 009s, Tr 90 011s, Tr 90 012s, Tr 90 033s, Tr 90 038s, Tr 90 039s).

Remarks: Pseudoristola sp. aff. *P. megalobosa* differs from the holotype of Yeh (1987) by having no H-link pattern around the joints.

Pseudoristola sp. A
Pl. 29, fig. 6
Cat. No. 3908/30.

Range: Lower Jurassic (Pliensbachian-Toarcian as far as known).

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s).

Remarks: Pseudoristola sp. A differs from other species within this genus by having a relatively small final bulbous chamber with only a few pores, this may be preservational.

Genus ***PARAHSUUM*** Yao, 1982

Type species: Parahsuum simplum

Range: Lower Jurassic

Occurrence (literature): Japan.
Occurrence (this study): West Timor, Indonesia.

Remarks: Parahsuum appears to be superficially similar to *Drulanta* Yeh, 1987 and *Droltus* Pessagno and Whalen, 1982, however, the pores are less regularly arranged between the costae and there are three or four tranverse rows of pores in each post-thoracic segment whereas in *Drulanta* there are only two. *Droltus* has more irregular pore frames proximally than *Parahsuum*.

Parahsuum ovale Hori and Yao, 1988
Pl. 28, fig. 4.
Cat. No. 3908/19

*1988 *Parahsuum ovale* Hori and Yao in Hori and Yao 1988.

Range: Lower Jurassic

Occurrence (literature): Japan.
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 9025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s)

Remarks: This species characteristically co-exists with *P. simplum* and occurs in part of a Lower Jurassic assemblage zone of Hori (1990).

?***Parahsuum*** sp. aff. ***P. simplum*** Yao, 1982
Pl. 28, figs. 5, 6, 7, 8, 9, 10, 11, 12, Pl. 29, fig. 10, 11.

Cat. Nos. 3909/7, 3909/4, 3909/9, 3908/32, 3909/37, 3908/33, 3908/18, 3908/38, 3909/35

*aff.1982 *Parahsuum simplum* Yao in Yao, p. 61, Pl. 4, figs. 1-8.

Range: Lower Jurassic

Occurrence (literature): Japan
Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 9025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s).

Remarks: ***P. simplum*** exhibits a wide variation within the species which is reflected in the specimens recovered during this study and characteristically ranges through much of the Lower Jurassic strata of Japan.

Genus *ARCHAEODICTYOMITRA* Pessagno, 1976

Type species: Archaeodictyomitra sqinabol Pessagno, 1976

Range: Lower Jurassic-Upper Cretaceous

Occurrence (literature): Worldwide
Occurrence (this study): West Timor, Indonesia.

Remarks: This genus occurs in low abundances in many samples.

?***Archaeodictyomitra*** sp. A
Pl. 29, fig. 9
Cat. No. 3909/30

Range: Lower Jurassic (as far as known)

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 027s, Tr 90 001s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 016s, Tr 90 017.1s, Tr 90 017.2s, Tr 90 018s, Tr 90 038s)

Remarks: This species is poorly preserved therefore its assignment to *Archaeodictyomitra* is questioned.

Genus ***ROLUMBUS*** Pessagno, Whalen and Yeh 1987

Type species: Rolumbus mirus Pessagno, Whalen and Yeh 1987

Range: Lower Jurassic (upper Pliensbachian-middle Toarcian)

Occurrence (literature): N. America
Occurrence (this study): West Timor, Indonesia.

Remarks: Rolumbus differs from *Farcus* by having two as opposed to one apical horn.

Rolumbus sp. A
Not illustrated
Cat. No. 90 002/7

Range: Lower Jurassic (Pliensbachian-Toracian)

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s, Tr 90 003s)

Remarks: This species occurs only rarely in the Lower Jurassic sediments of West Timor.

NASSELLARIINA **incertae sedis**

Genus ***TRICOLOCAPSA*** Haeckel, 1881

Type species: Tricolocapsa theophrasti Haeckel, 1881.

Range: Mesozoic

Occurrence (literature): Worldwide
Occurrence (this study): West Timor, Indonesia

Remarks: This genus has a very long range throughout the Mesozoic.

Tricolocapsa sp. A
Not illustrated
Cat. No. 90 002/8

Range: Lower Jurassic

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 002s)

Remarks: This species exhibits a great deal of variation in ornament.

Nassellarian gen. and sp. indet. C
Pl. 29, fig. 1.
Cat. No. 3906/1

Range: Lower Jurassic (Pliensbachian-Toarcian, as far as known)

Occurrence (this study): Noil Meto, Soe, West Timor, Indonesia (Sample Tr 90 025s)

Remarks: This genus is similar to *Globolaxtorum* Carter, 1993, however, lacks spines on the inflated post abdominal chamber.

PLATE 1

Explanation of Plate 1

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 11. *Capnodoce anapetes* De Wever, 1979 emend. Blome, 1983, 1=3073/8, 11=3073/27. Scale bar: 1=150µm, 11=88µm. Sample 246, 233-234, 223.

2, 3. *Capnodoce fragilis* Blome, 1983, 2=3020/15, 3=3054/5. Scale bar: 2=190µm, 3=200µm. Sample 231, 223.

4, 5. *Capnodoce insueta* Blome, 1983, 4=3015/23, 5=3015/25. Scale bar: 4=192µm, 5=200µm. Sample 232, 239, 223, 216-217-218, 99+101.

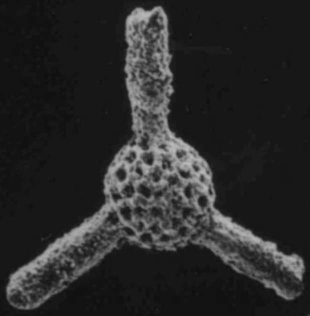
6. *Capnodoce kochi* Blome, 1983 6=3020/11. Scale bar: 6=150µm. Sample 246, 239, 229, 223.

7. *Capnodoce* sp. A, 7=3054/2. Scale bar: 7=150µm. Sample 232.

8, 9. *Capnodoce* sp. B, 8=3020/14, 9=3020/13. Scale bar: 8=190µm, 9=190µm. Sample 232

10. *Capnodoce* sp. aff. *C. copiosa* Blome, 1983, 10=3057/3. Scale bar: 10=90µm. Sample 232, 246, 223.

PLATE 1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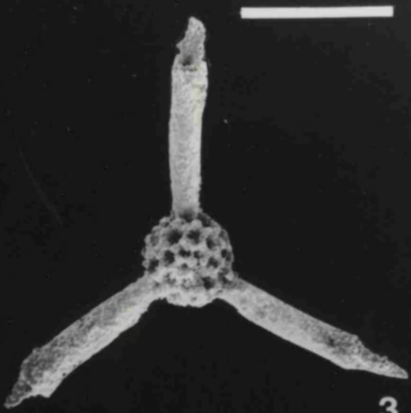
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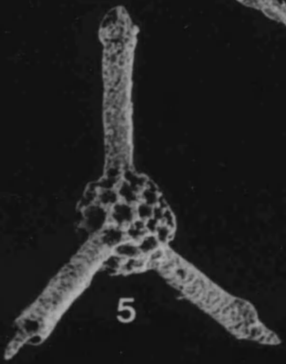
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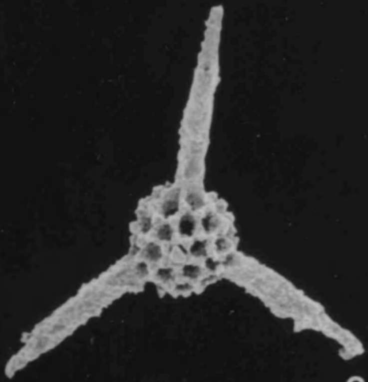
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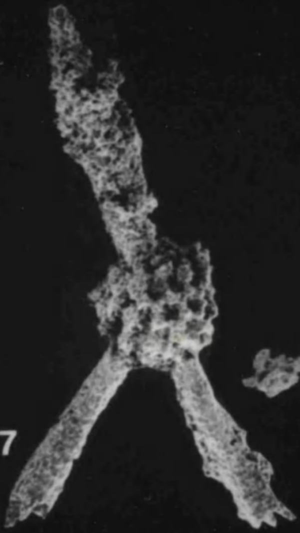
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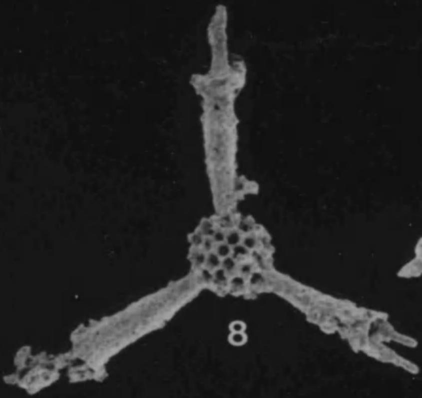
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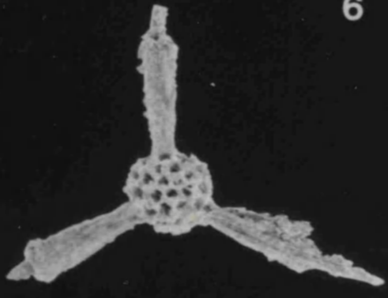
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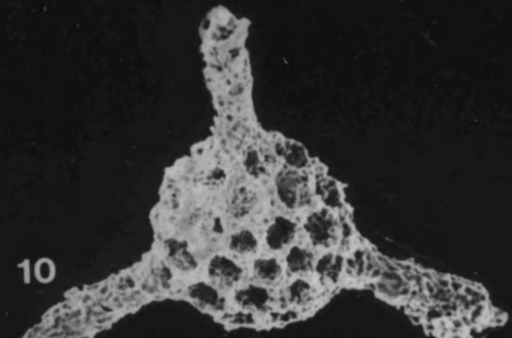
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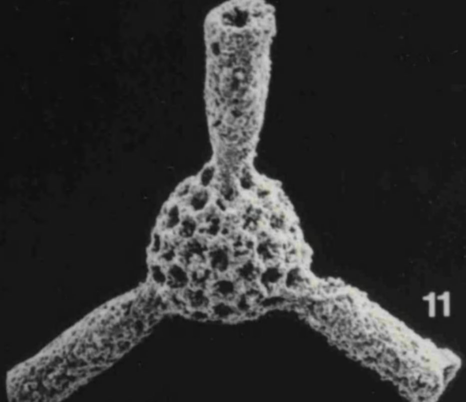
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PLATE 2

Explanation of Plate 2

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 3. *Capnodoce* sp. B, 1=3020/12, 3=3020/9. Scale bar: 1=200μm, 3=195μm. Sample 232.

2. *Capnodoce fragilis* Blome, 1983, 2=3020/10. Scale bar: 2=155μm. Sample 231, 223.

4, 5. *Loffa lepida* Blome, 1983, 4=3053/34, 5=3053/34. Scale bar: 4=200μm, 5=200μm. Sample 232

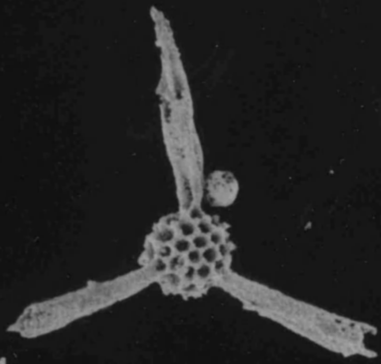
6, 10, 11. *Loffa* sp. A 6=3020/8, 10=3053/33, 11=3073/9. Scale bar: 6=200μm, 10=160μm, 11=86μm.Sample 232.

7. *Loffa* sp. B, 7=3054/2. Scale bar: 7=160μm. Sample 232.

9. *Renzium adversum* Blome, 1983, 9=3275/35. Scale bar: 9=150μm. Sample 232, 239, 223, 216-217-218.

8. *Renzium* sp. A, 8=3057/16. Scale bar: 8=150μm. Sample 232.

PLATE 2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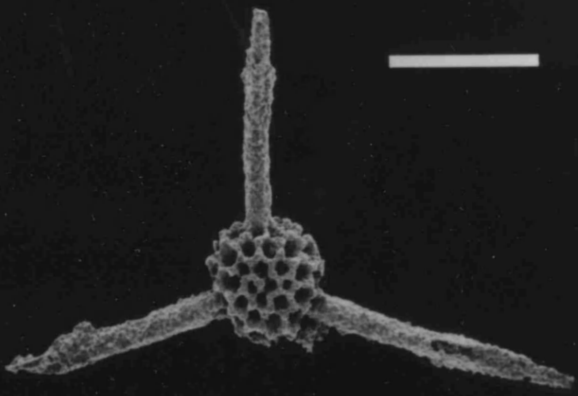
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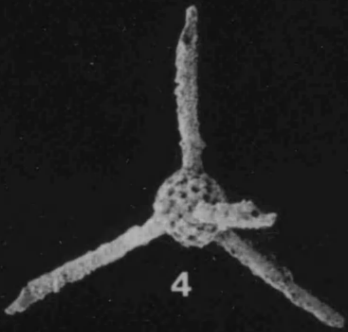
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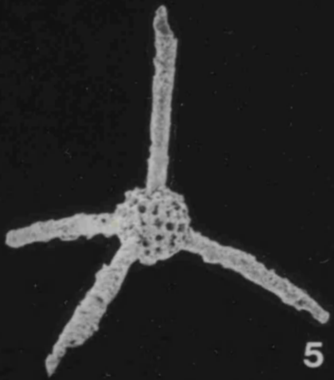
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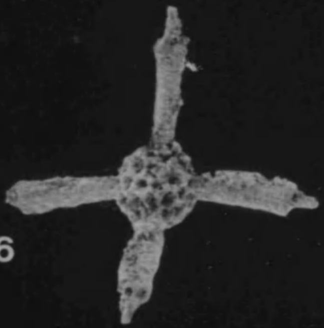
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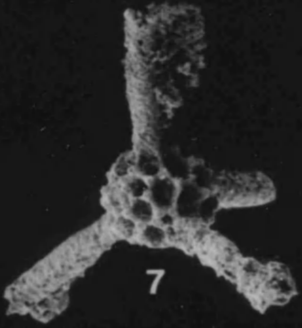
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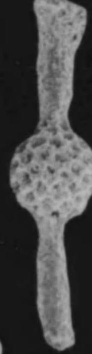
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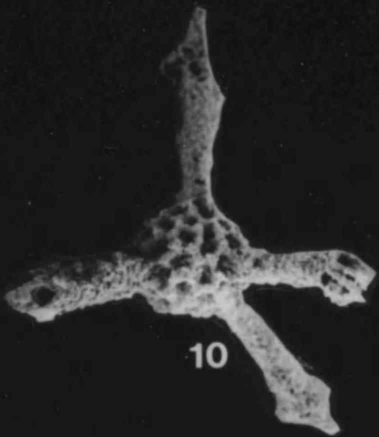
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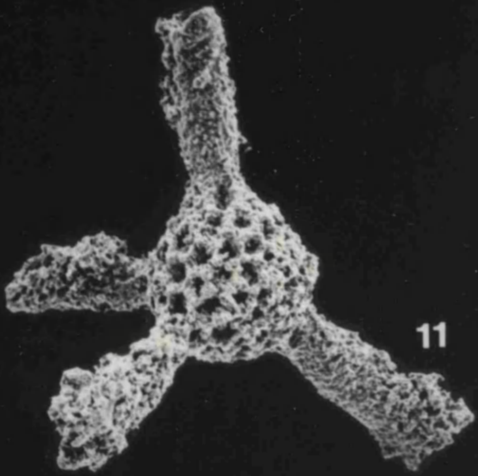
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PLATE 3

Explanation of Plate 3

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

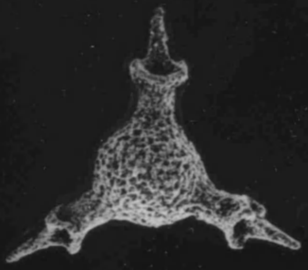
1, 2, 3, 12. *Capnuchosphaera colemani* Blome, 1983 1=3074/18, 2=3074/13, 3=3073/16, 12=3074/19. Scale bar: 1=150µm, 2=160µm, 3=150µm, 12=30µm. Figure 12 is an enlargment of the arm of *C. colemani.* Sample 246, 232.

4, 10, *Capnuchosphaera triassica* De Wever, 1979 4=3044/2, 10=3100/31. Scale bar: 4=155µm, 10=185µm. Sample 232, 246, 223, 216-217-218.

5, 6, *Capnuchosphaera triassica* De Wever, 1979, 5=3251/9, 6=3073/11.Scale bar: 5=155µm, 6=160µm. Sample 232, 246, 223, 216-217-218.

7, 8, 9, 11 13. *Capnuchosphaera triassica* De Wever, 1979, 7=3074/30, 8=3074/16, 9=3074/26, 11=3074/26, 13=3073/12. Scale bar: 7=170µm, 8=155µm, 9=150µm, 11=75µm, 13=88µm. The wide variation within *C. triassica* illustrated in figures 4-11 and 13. Sample 232, 246, 223, 216-217-218.

PLATE 3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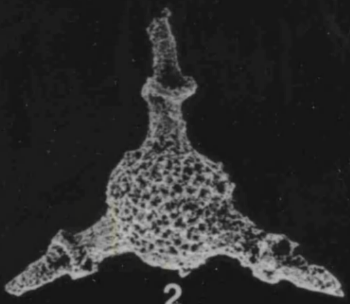
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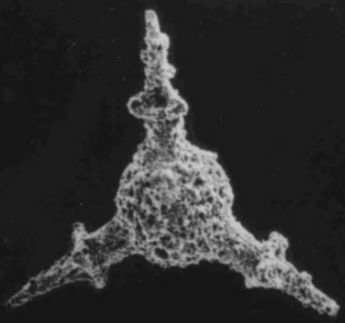
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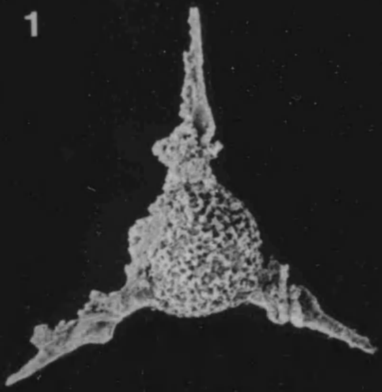
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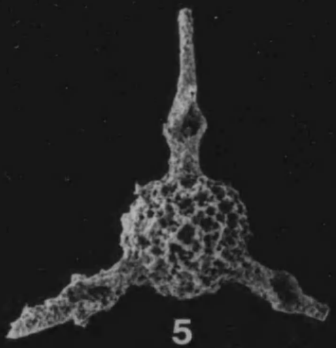
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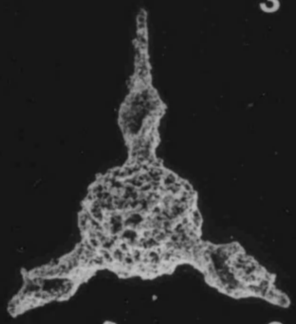
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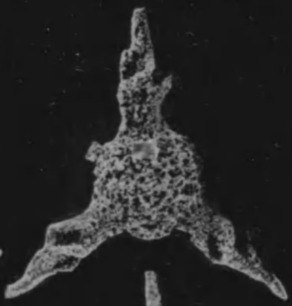
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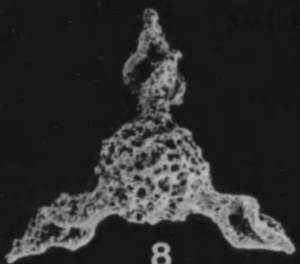
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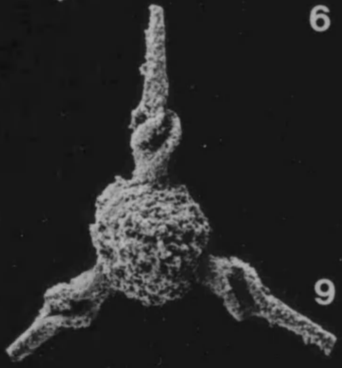
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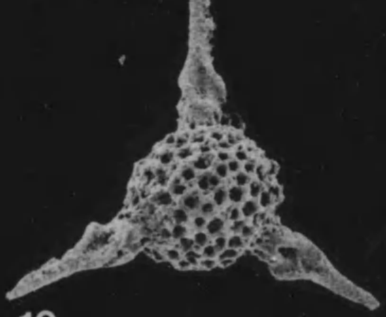
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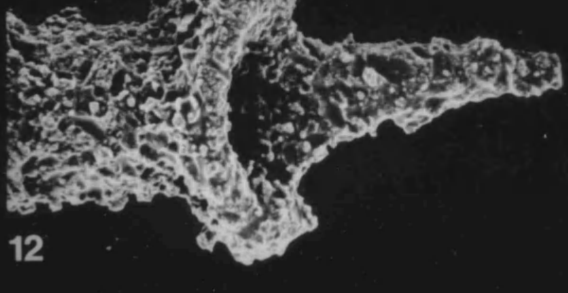
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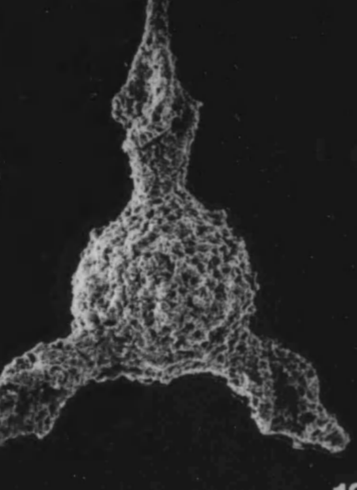
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PLATE 4

Explanation of Plate 4

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 2. *Capnuchosphaera schenki* Blome, 1983 1=3073/15, 2=3073/7. Scale bar: 1=150µm, 2=150µm. Sample 232.

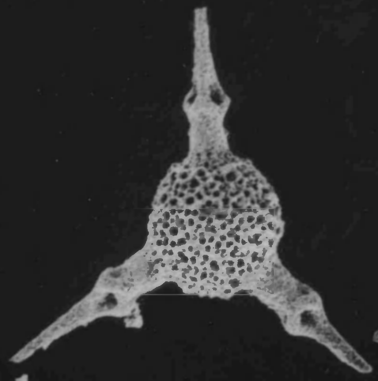
3. *Capnuchosphaera* sp.aff. *C. smithorum* Blome, 1983 3=3100/13. Scale bar: 3=150µm. Sample 232.

4, 5, 9, 10, 11. *Capnuchosphaera* sp. aff *C. theloides* De Wever, 1979 4=3074/21, 5=3054/19, 9=3074/21, 10=3074/21, 11=3074/21. Scale bar: 4=160µm, 5=150µm, 9=100µm, 10=45µm, 11=80µm. Sample 246, 232, 223, 216-217-218.

6. *Vinassaspongus* sp. A 6=3252/5. Scale bar: 6=155µm. Sample 223, 246, 232.

7, 8. *Capnuchosphaera* sp. A, 7=3100/20, 8=3100/21. Scale bar: 7=150µm, 8=82µm. Sample 232, 231, 229.

PLATE 4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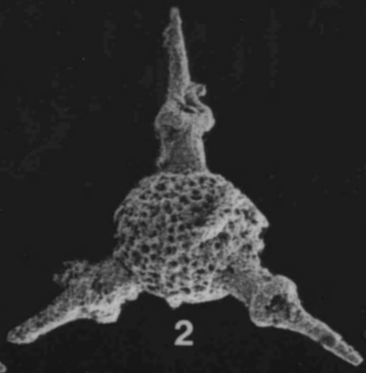
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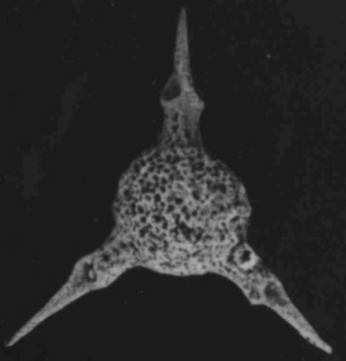
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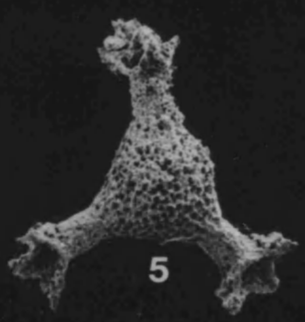
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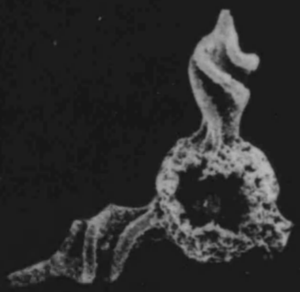
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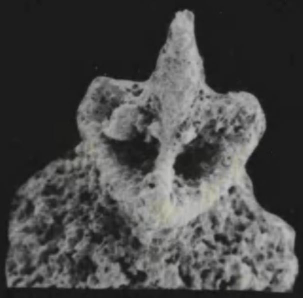
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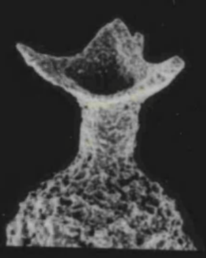
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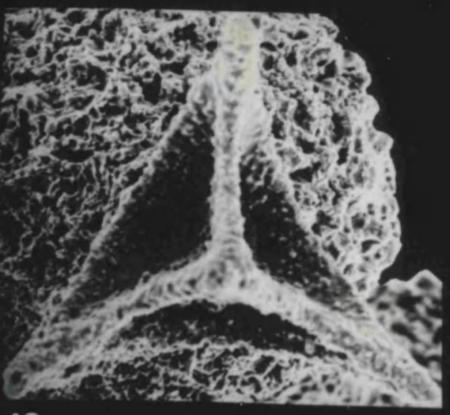
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PLATE 5

Explanation of Plate 5

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

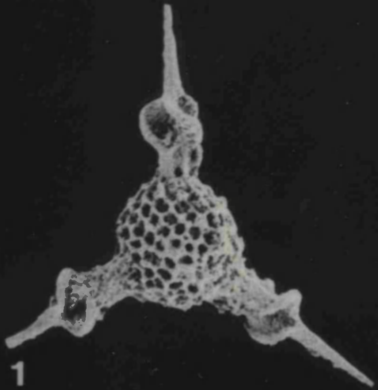
1, 13. *Capnuchosphaera timorensis* n. sp. Holotype = 1=3100/20, 13=3100/20. Scale bar: 1=200µm, 13=50µm. Sample 232, 231, 246.

2, 3, 4, 5, 6. *Capnuchosphaera timorensis* n. sp. Paratypes = 2=3100/26, 3=3074/12, 4=3100/30, 5=3056/29, 6=3100/24. Scale bar: 2=192µm, 3=160µm, 4=180µm, 5=185µm, 6=150µm. Sample 232, 231, 246.

10,11 12. *Capnuchosphaera timorensis* n. sp. Paratypes = 10=3056/29, 11=3100/30, 12=3100/26. Scale bar: 10=85µm, 11=100µm, 12=90µm. Sample 232, 231, 246.

7, 8, 9. *Capnuchosphaera* sp. aff. *C. theloides* De Wever, 1979 7=3747/12, 8=3251/31, 9=3747/10. Scale bar: 7=138µm, 8=90µm, 9=135µm. Sample 246, 232, 223, 216-217-218.

PLATE 5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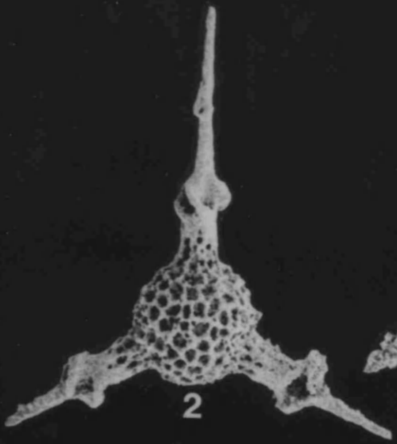
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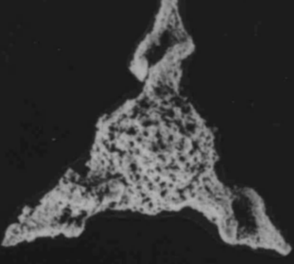
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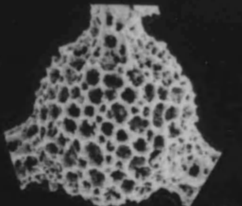
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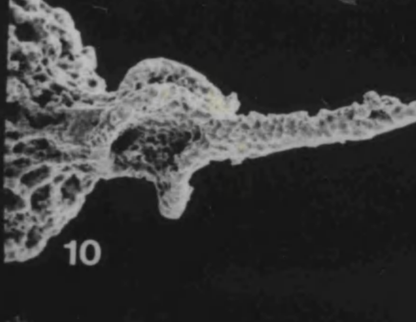
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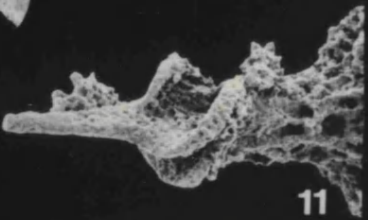
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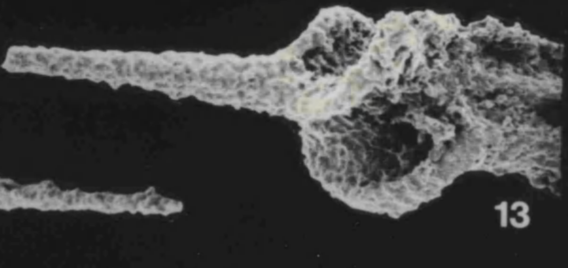
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PLATE 6

Explanation of Plate 6

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

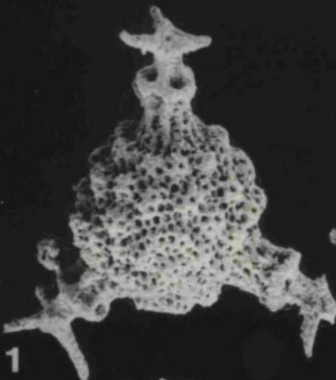
1, 9. *Capnuchosphaera metoensis* n. sp. Holotype = 1=3054/13. Scale bar: 1=160µm, 9=35µm. Sample 232, 231, 223.

2, 3, 4, 5, 7. *Capnuchosphaera metoensis* n. sp. Paratypes = 2=3251/27, 3=3054/10, 4=3026/2, 5=3251/2, 7=3024/31. Scale bar: 2=160µm, 3=145µm, 4=162µm, 7=150µm. Sample 232, 231, 223.

6, 10. *Capnuchosphaera kapanensis* n. sp. Holotype = 6=3054/25, 10=3054/25. Scale bar: 6=150µm, 10=82µm. Sample 232, 231, 223.

8, 11. *Capnuchosphaera kapanensis* n. sp. Paratypes = 8=3054/22, 11=3054/25. Scale bar: 8=155µm, 11=82µm. Sample 232, 231, 223.

PLATE 6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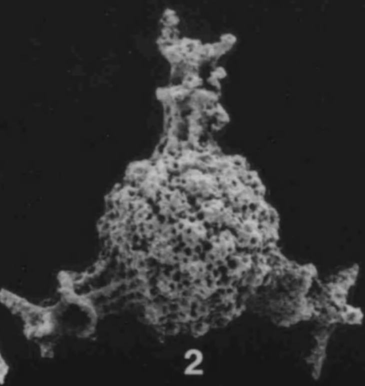
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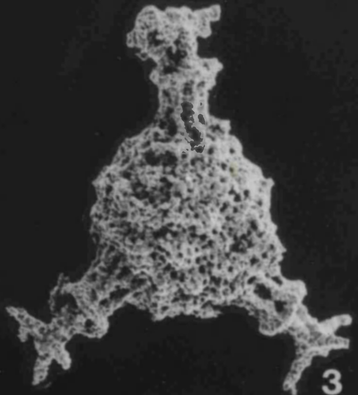
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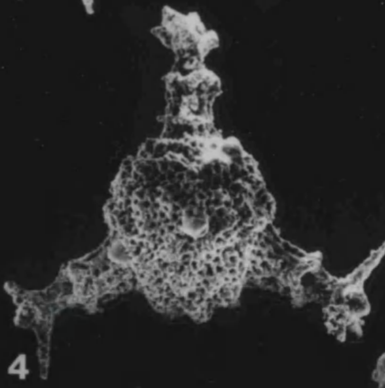
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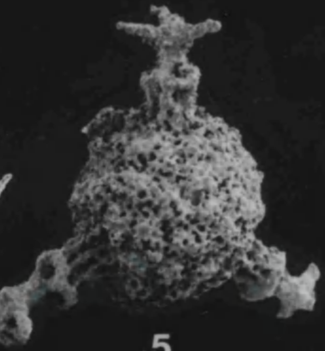
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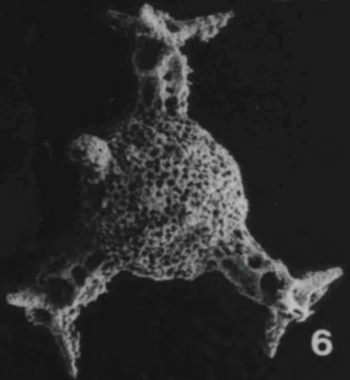
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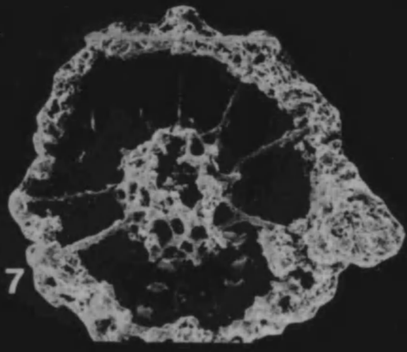
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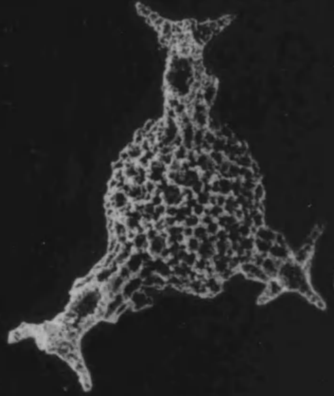
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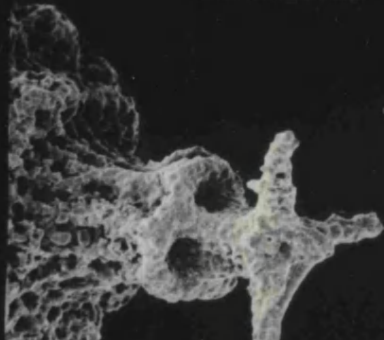
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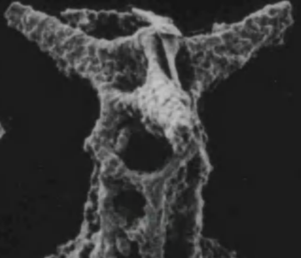
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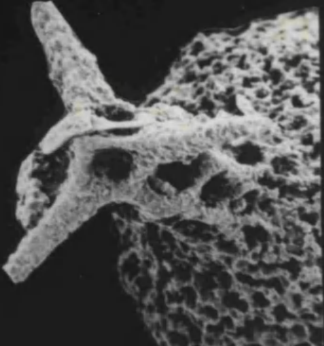
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PLATE 7

Explanation of Plate 7

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1. *Capnuchosphaera constricta* (Kozur and Mostler, 1981) 1=3044/1. Scale bar: 1=220μm. Sample 232, 223, 216-217-218.

2, 9, 10. *Capnuchosphara* sp. B 2=3100/22, 9=3100/22, 10=3100/22. Scale bar: 2=210μm, 9=125μm, 10=88μm. Sample 232.

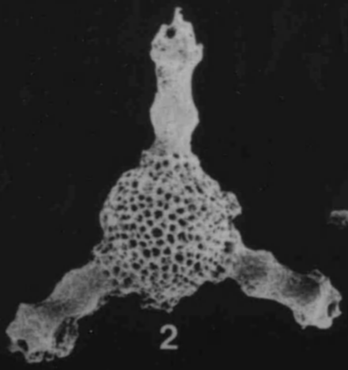
3, 7. *Icrioma* sp. aff. *I. tetrancistrum* De Wever, 1979 3=3074/17, 7=3074/17. Scale bar: 3=165μm, 7=98μm. Sample 246, 223.

4, 5. *Capnuchosphaera metoensis* n. sp. Paratypes = 4=3026/3, 5=3026/4. Scale bar: 4=150μm, 5=165μm. Sample 223, 231, 232.

6, 8. *Capnuchosphaera* sp. aff. *C. constricta* (Kozur and Mostler, 1981) 6=3057/9, 8=3057/9. Scale bar: 6=150μm, 8=65μm. Sample 232.

PLATE 7


1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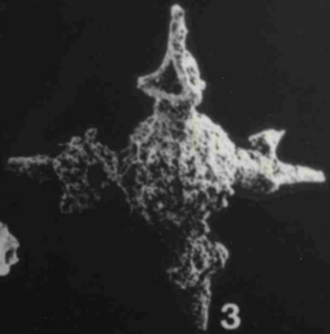
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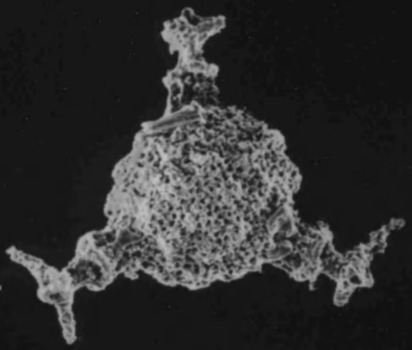
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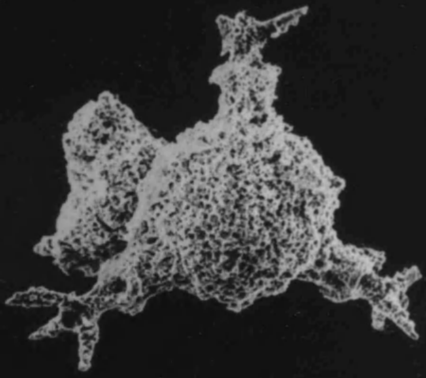
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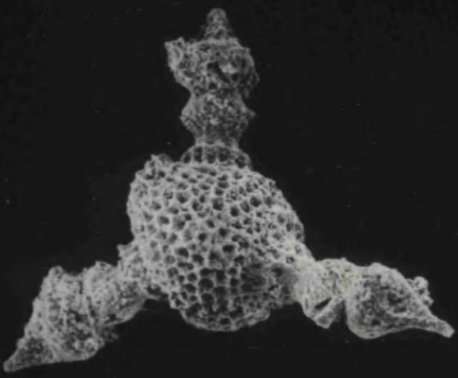
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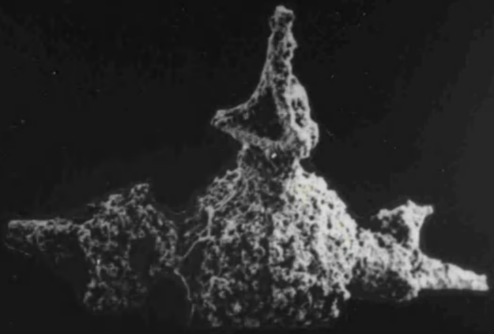
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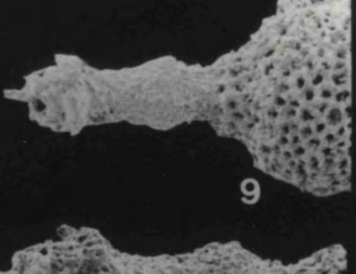
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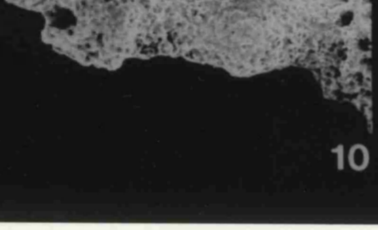
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PLATE 8

Explanation of Plate 8

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1. *Paronaella* sp. aff. *bifida* Carter, 1993 1=3208/27. Scale bar: 1=205µm. Sample 220.

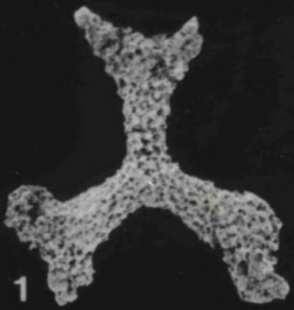
2. *Paronaella leebyi* n. sp. Holotype = 2=3208/25. Scale bar: 2=198µm. Sample 220, 224, 213.

3, 4. *Paronaella leebyi* n. sp. Paratypes = 3=3208/24, 4=3208/26. Scalebar: 3=205µm, 4=178µm. Sample 220, 224, 213.

6, 7, 9, 10, 11. *Homeoparonaella norica* Kozur and Mock, 1981. 6=3045/6, 7=3045/13, 9=3045/6, 10=3045/11, 11=3045/11. Scale bar: 6=156µm, 7=148µm, 9-173µm, 10=173µm, 11=42µm. Sample 232, 246, 224, 223.

5, 8, 12, 13. *Paronaella* sp. A 5=3045/8, 8=3045/9, 12=3045/8, 13=3045/8. Scale bar: 5=148µm, 8=142µm, 12=102µm, 13=107µm. Sample 232, 242, 241, 216-217-218.

PLATE 8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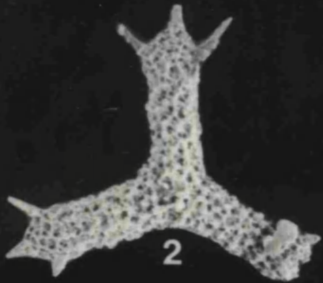
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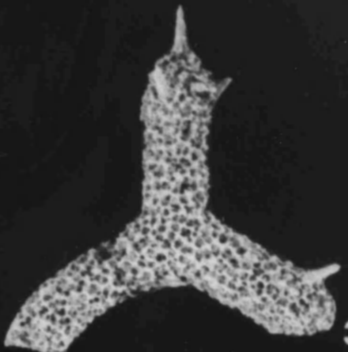
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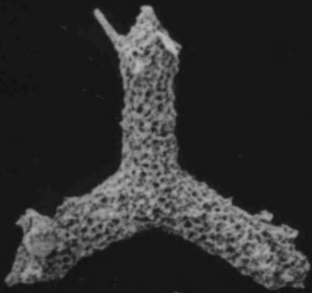
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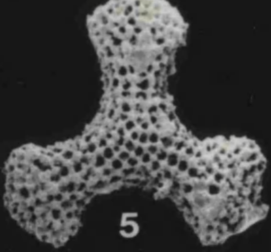
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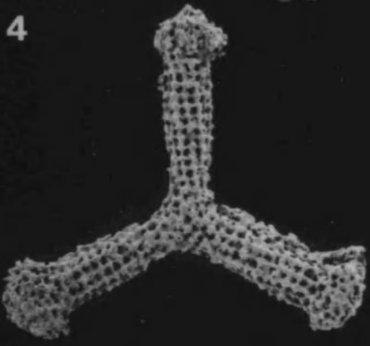
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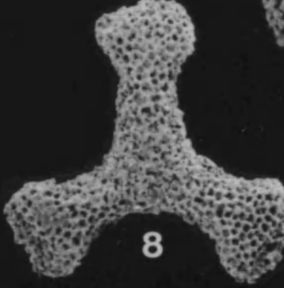
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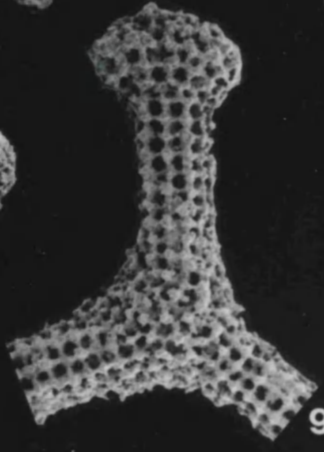
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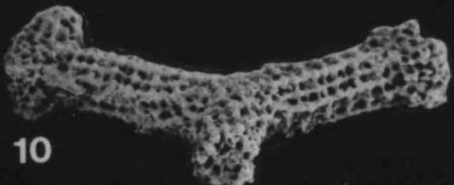
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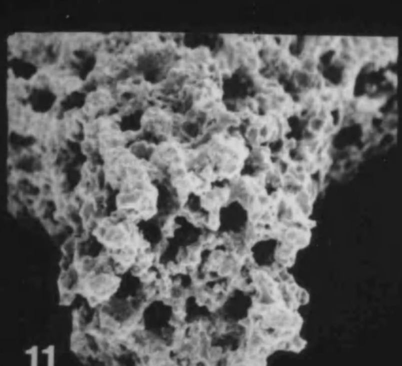
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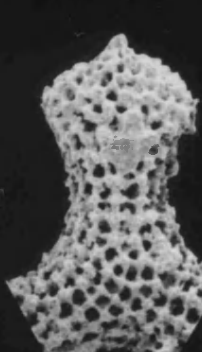
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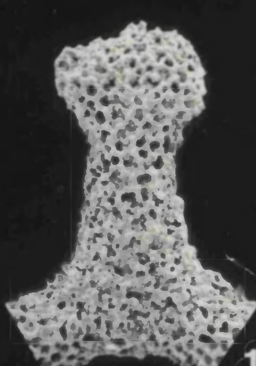
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PLATE 9

Explanation of Plate 9

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 2, 3, 11. *Pentactinocarpus aspinosus* Kozur and Mostler, 1981 1=3020/18, 2=3015/17, 3=3020/17, 11=3251/34. Scale bar: 1=203µm, 2=197µm, 3=198µm, 11=138µm. Sample 231, 232, 220.

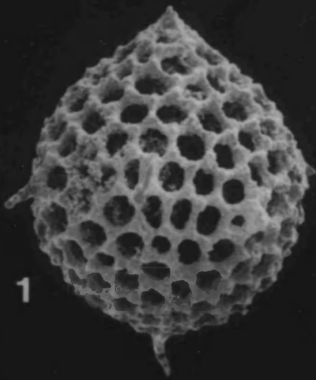
4, 5. *Pentactinocarpus sevaticus* Kozur and Mostler, 1981, 4=3251/6, 5=3208/32. Scale bar: 4=172µm, 5=175µm. Sample 220.

6. *Pentactinocarpus longispinosus* n. sp. Holotype = 6=3020/19. Scale bar: 6=158µm. Sample 231, 232, 223.

7, 9, 10. *Pentactinocarpus longispinosis* n. sp. Paratypes = 7=3251/38, 9=3251/36, 10=3251/35. Scale bar: 7=162µm, 9=161µm, 10=108µm. Sample 231, 232, 223.

8. *Pentactinocarpus* sp. A 8=3078/33. Scale bar: 8=85µm. Sample 246, 232.

PLATE 9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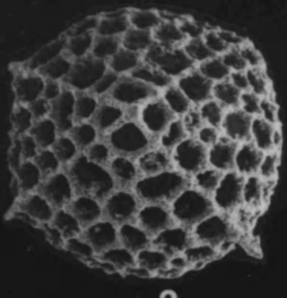
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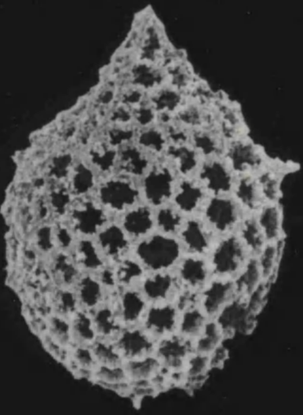
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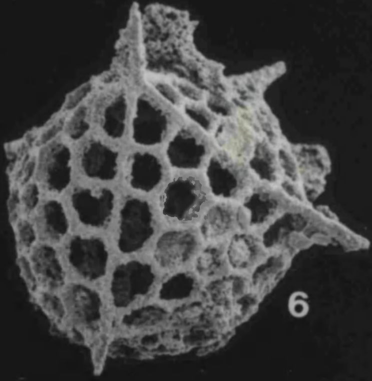
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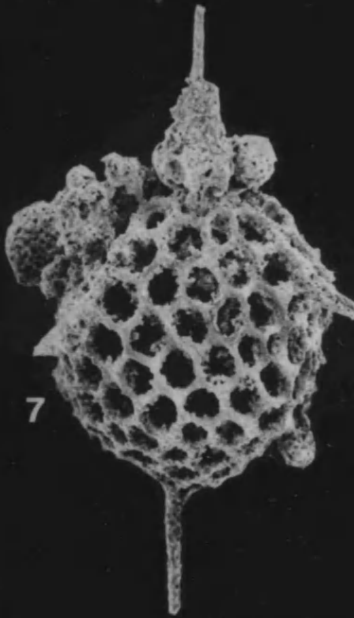
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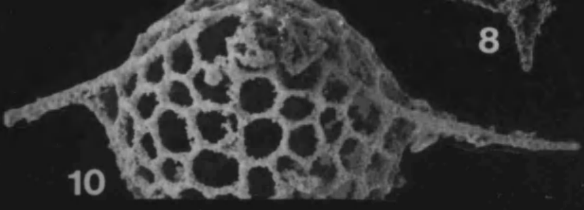
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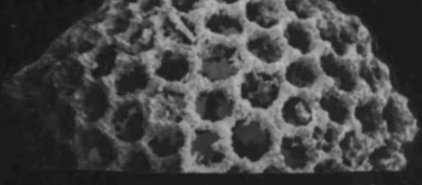
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PLATE 10

Explanation of Plate 10

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 2. *Crucella* sp. A 1=3020/17, 2=3054/9. Scale bar: 1=147µm, 2=161µm. Sample 232, 233-234, 231, 224, 223, 216-217-218, 209 (a).

3. *Paronaella* sp. B 3=3251/6. Scale bar: 3=143µm. Sample 246, 232.

4. *Pentaporobrachia* sp. A 4=3208/32. Scale bar: 4=207µm. Sample 220.

5. *Triassocrucella* sp. A 5=3073/25. Scale bar: 5=185µm. Sample 246.

6. *Pseudohagiastrum monstruosum* Pessagno, 1979 6=3056/31. Scale bar: 6=87µm. Sample 232

7. *Tetraporobrachia composita* Carter, 1993 7=3208/33. Scale bar: 7=212µm. Sample 220, 228.

8. *Paratriassoastrum?* sp. A 8=3208/29. Scale bar: 8=304µm. Sample 220.

9. *Tetraporobrachia longispinosa* n. sp. Holotype = 9=3208/34. Scale bar: 9=194µm. Sample 220.

10, 11. *Pseudohagiastrum longabrachiatum* Carter, 1993 10=3208/30, 11=3208/11. Scale bar: 10=196µm, 11=213µm. Sample 220.

PLATE 10

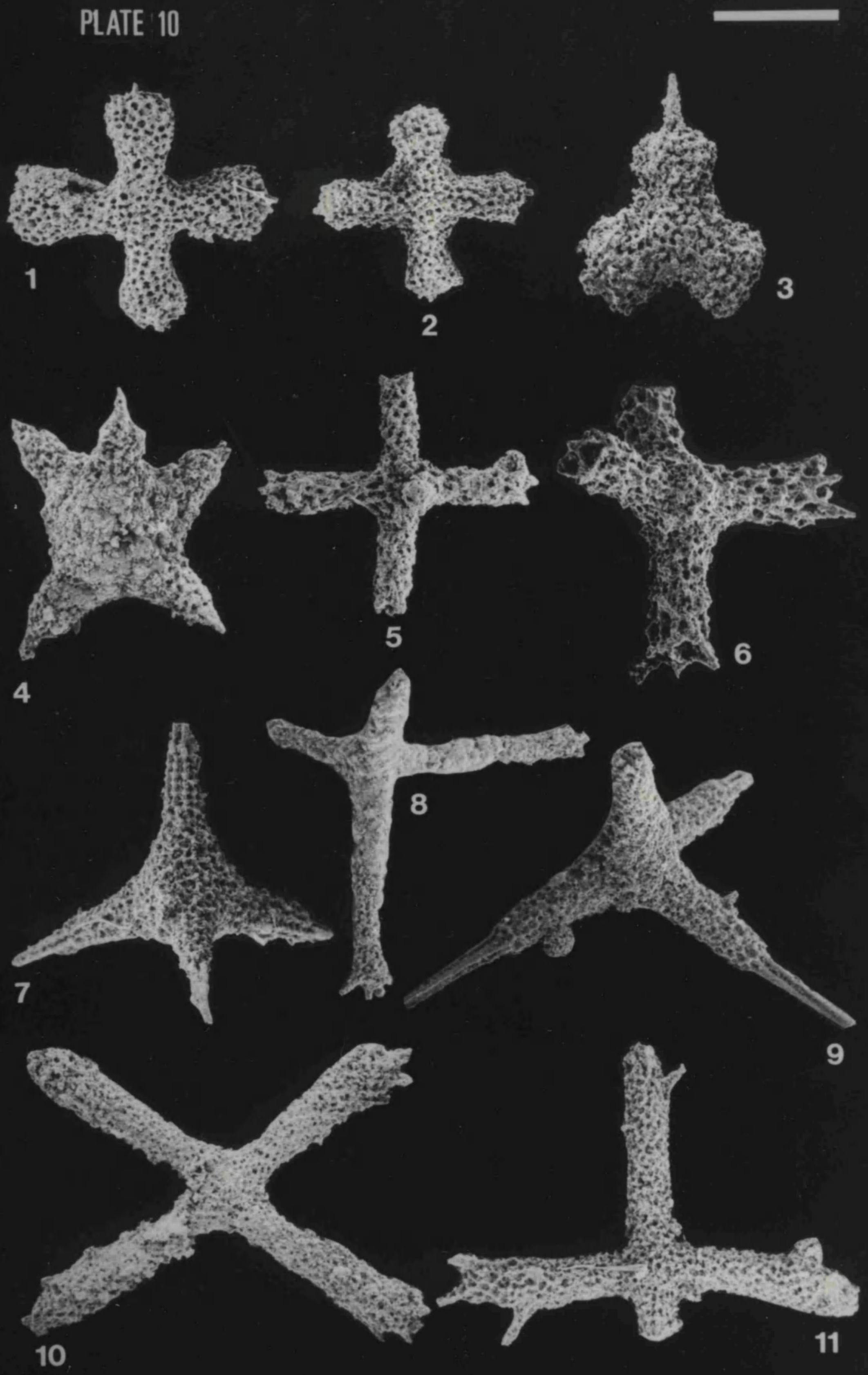


PLATE 11

Explanation of Plate 11

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 2. *Kahlerosphaera aspinosa* Kozur and Mostler, 1981 1=3073/35, 2=3073/22. Scale bar: 1=139µm, 2=164µm. Sample 246, 232.

3. *Kahlerosphaera norica* Kozur and Mostler, 1981 3=3026/26. Scale bar: 3=200µm. Sample 232, 231.

4. *Kahlerosphaera ~~P~~petalouda* n. sp. Holotype = 4=3251/3. Scale bar: 200µm. Sample 223, 232.

5, 9. *Kahlerosphaera* sp. aff. *K. norica* Kozur and Mostler, 1981 5=3026/13, 9=3054/7. Scale bar: 5=200µm, 9=187µm. Sample 232, 246.

6, 7. *Kahlerosphaera* sp. aff. *K. aspinosa* Kozur and Mostler, 1981 6=3054/12, 7=3054/16. Scale bar: 6=167µm, 7=200µm. Sample 232, 246.

8. ?*Kahlerosphaera* sp. aff. *K, longispinosa* Kozur and Mostler, 1979 8=3073/16. Scale bar: 8=200µm. Sample 223, 232, 246.

10, 12. *Orbiculaforma tethyus* De Wever, 1979 10=3054/29, 12=3100/16. Scale bar: 10=178µm, 12=183µm. Sample 232, 233-234, 231, 223.

11. *Orbiculaforma kyklica* n. sp. Holotype = 11=3054/24. Scale bar: 11=179µm. Sample 232, 231, 223.

PLATE 11

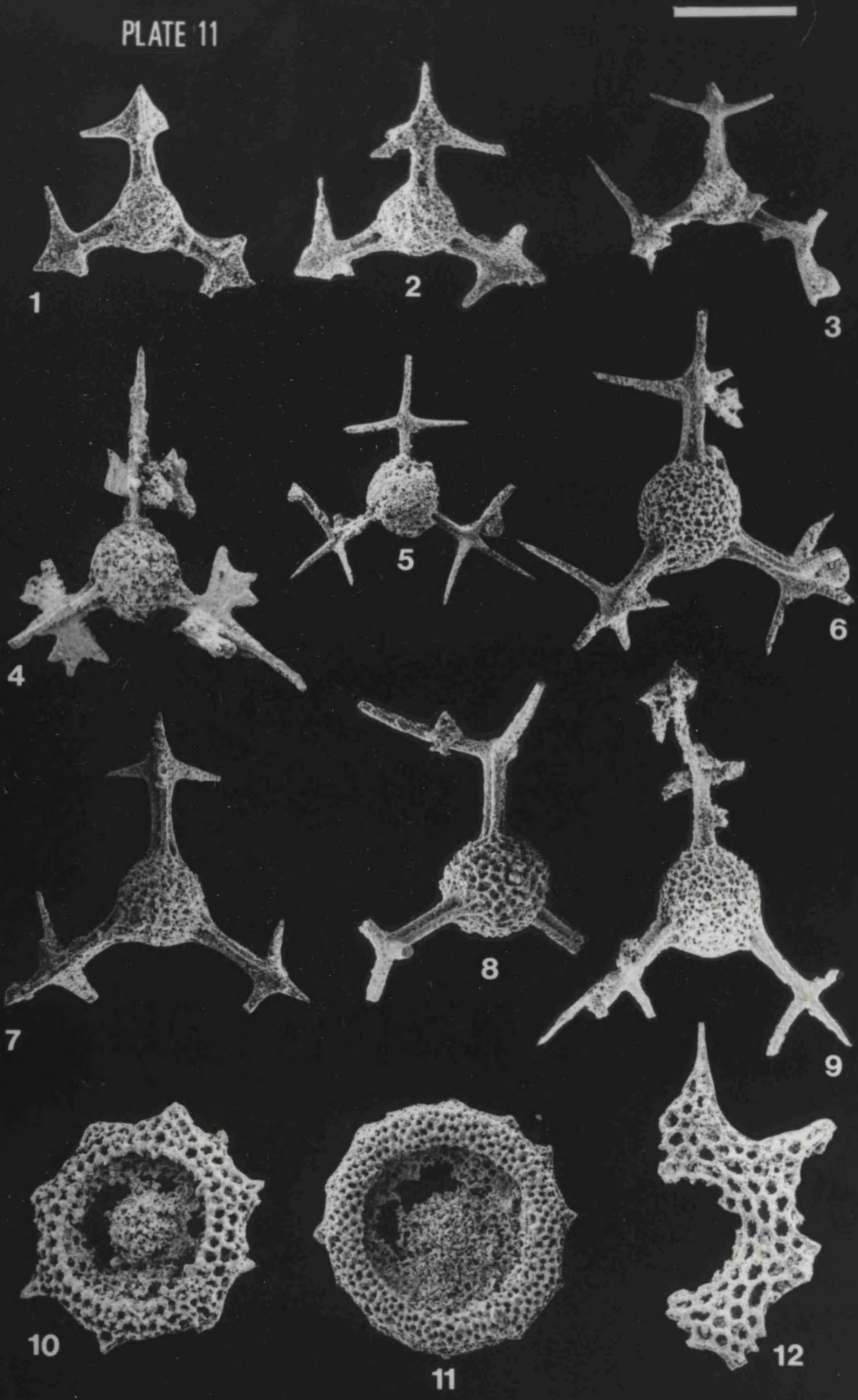


PLATE 12

Explanation of Plate 12

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1. *Pantanellium* sp. A 1=3747/6. Scale bar: 1=95µm. Sample 232, 220.

2. *Pantanellium* sp. B 2=3747/4. Scale bar: 2=60µm. Sample 232.

3, 4. *Gorgansium* sp. B 3=3746/1, 4=3746/8. Scale bar: 3=100µm, 4=100µm. Sample 232.

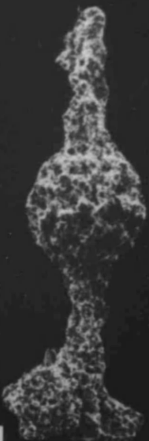
5. *Gorgansium* ? sp. A 5=3746/3. Scale bar: 5=48µm. Sample 232, 231, 246.

6, 7. *Gorgansium* sp. C 6=3746/2, 7=3746/7. Scale bar: 6=75µm, 7=88µm. Sample 232, 205.

8, 9, 10. *Justium*? sp. A Blome, 1983, 8=3746/12, 9=3746/11, 10=3746/5. Scale bar: 8=54µm, 9=58µm, 10=72µm. Sample 232.

11, 12. *Poulpus piabyx* De Wever, 1979 11=3057/12, 12=3057/12. Scale bar: 11=88µm, 12=150µm. Sample 223.

PLATE 12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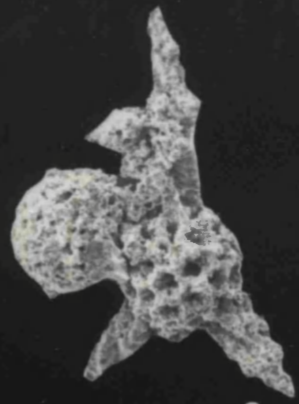
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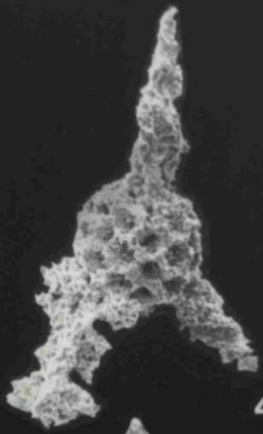
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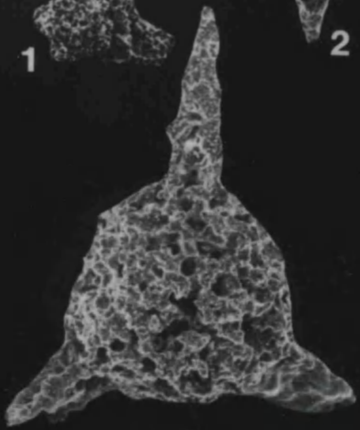
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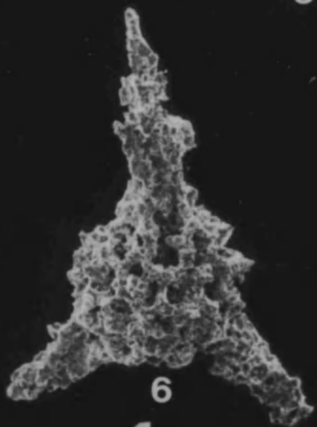
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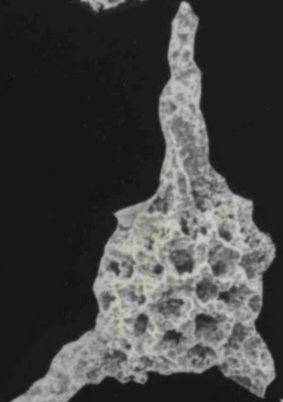
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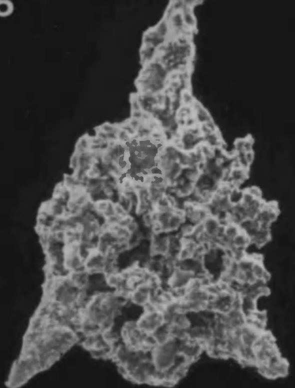
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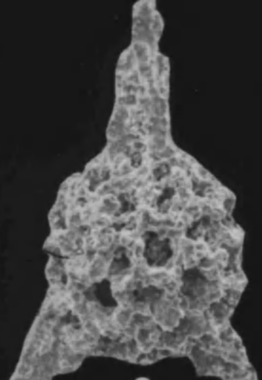
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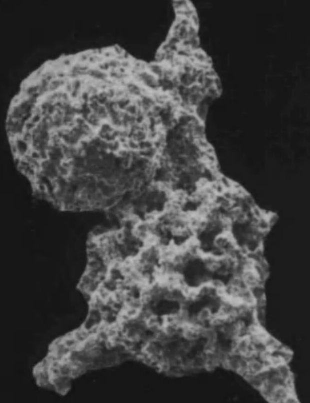
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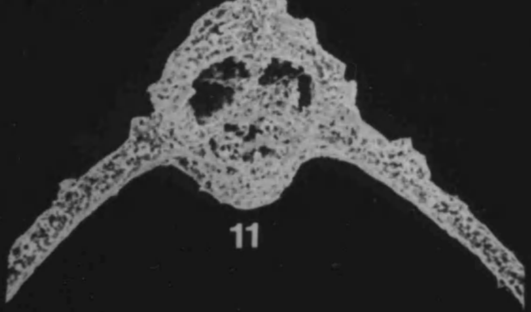
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PLATE 13

Explanation of Plate 13

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 2, 12. *Crucella* sp. A 1=3054/31, 2=3026/9, 12=3251/1. Scale bar: 1=42µm, 2=145µm, 12=87µm. Sample 232, 233-234, 231, 224, 223, 216-217-218, 205 (a).

3, 4, 5, 6. *Livarella densiporata* Kozur and Mostler, 1981 3=3914/6, 4=3914/6, 5=3914/7, 6=3914/9. Scale bar: 3=94µm, 4=90µm, 5=60µm, 6=82µm. Sample 220, Tr 90 009s

7. *Livarella* sp. A 7=3608/19. Scale bar: 7=114µm. Sample Tr 90 021s.

8. *Pseudolivarella barkhami* n. gen. and n. sp. Holotype = 8=3608/12. Scale bar: 8=163µm. Sample 224, 213.

9. *Pseudolivarella barkhami* n. gen. and n. sp. Paratype = 9=3608/13. Scale bar: 9=150µm. Sample 224, 213.

10. *Paratriassoastrum*? sp. A 10=3020/2. Scale bar: 10=30µm. Sample 220.

11. ?*Pseudohagiastrum* sp. A 11=3251/6. Scale bar: 11=172µm. Sample 231.

PLATE 13

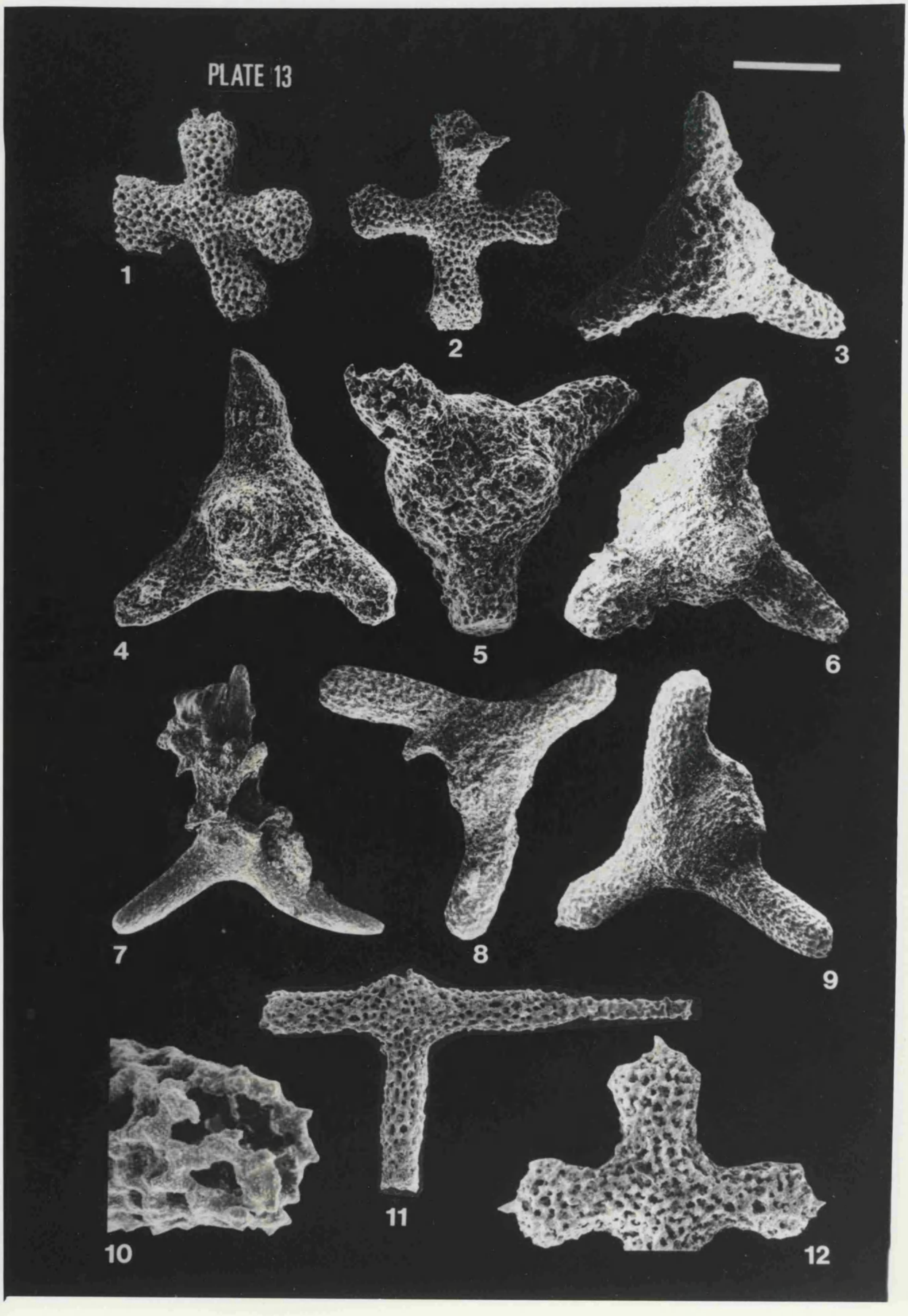


PLATE 14

Explanation of Plate 14

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 2. *Tetraporobrachia* sp. A 1=3074/24, 2=3074/24. Scale bar: 1=154 µm, 2=154µm. Sample 246.

3. *Saitoum* sp. A 3=3251/10. Scale bar: 3=158µm. Sample 223.

4. *Citraduma* sp. A 4=3100/6. Scale bar: 4=210µm. Sample 220, 224.

5. *Citraduma* sp. B 5=3100/5. Scale bar: 5=215µm. Sample 220, 224.

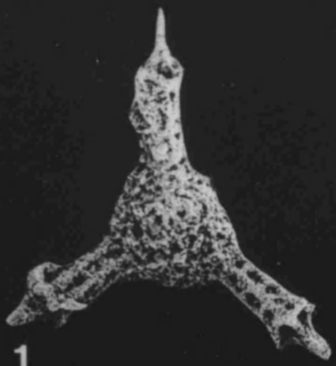
6. *Citraduma* sp. C 6=3100/4. Scale bar: 6=212µm. Sample 220.

7, 8, 9. *Astrocentrus* sp. aff. *A. pulcheri* Kozur and Mostler, 1979 7=3073/4, 8=3054/28, 9=3101/12. Scale bar: 7=152µm, 8=163µm, 9=170µm. Sample 232, 246, 220.

10. *Heliosoma* sp. aff. *H. carinata* Kozur and Mostler, 1979 10=3214/9. Scale bar: 10=95µm. Sample 231, 232, 246.

11, 12. *Heliosoma* sp. aff. *H. mocki* Kozur and Mostler, 1979 11=3026/10, 12=3073/6. Scale bar: 11=86µm, 12=88µm. Sample 246, 232, 223.

PLATE 14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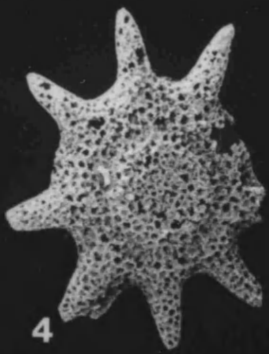
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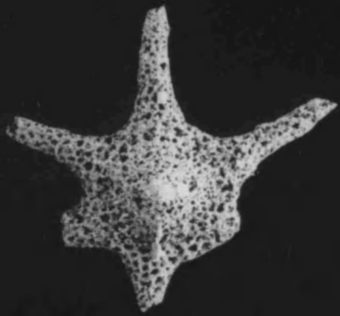
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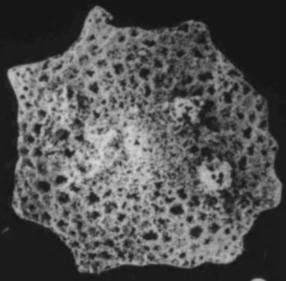
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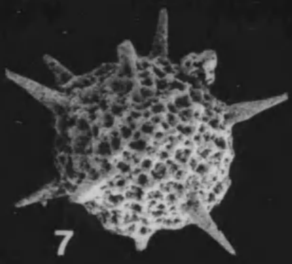
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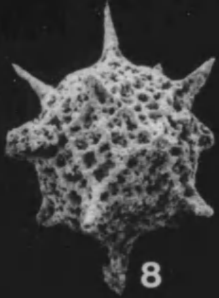
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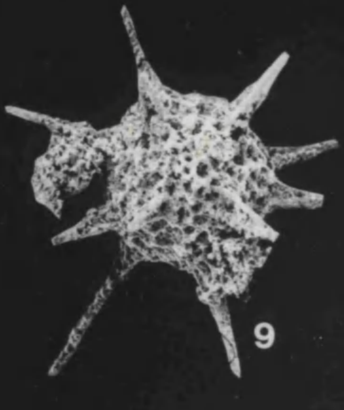
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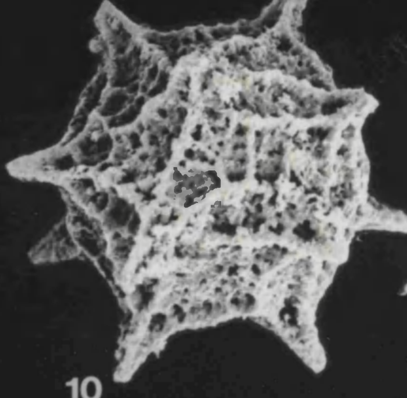
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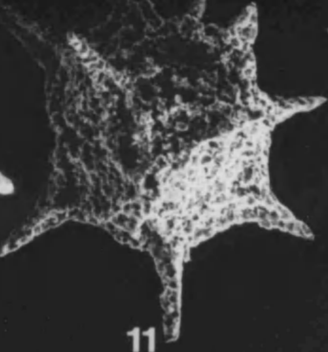
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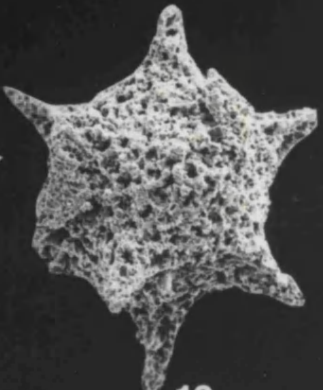
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PLATE 15

Explanation of Plate 15

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 9. *Cantalum* sp. aff. *C. holdsworthi* Pessagno, 1979 1=3074/27, 9=3073/18. Scale bar: 1=162µm, 9=83µm. Sample 246, 220, 216-217-218.

2. *Ferresium loganense* Blome, 1984 2=3073/28. Scale bar: 2=152µm. Sample 246, 232.

3. *Sarla longispinosum* Kozur and Mostler, 1979 emend. Blome, 1983 3=3057/18. Scale bar: 3=300µm. Sample 232, 223.

4. *Pseudohagiastrum* sp. aff. *P. monstruosum* Pessagno, 1979 4=3074/32. Scale bar: 4=89µm. Sample 246.

5. *Ferresium* sp. A 5=3747/17. Scale bar: 5=110µm. Sample 216-217-218. Sample 216-217-218, 231, 232.

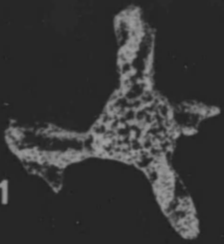
6. *Betraccium deweveri* Pessagno and Blome, 1980 6=3100/7. Scale bar: 6=104µm. Sample 220.

7. *Cantalum holdsworthi* Pessagno, 1979 7=3073/23. Scale bar: 7=86µm. Sample 246, 220, 216-217-218.

8. *Cantalum* sp. aff. *C. globosum* Blome, 1984 8=3101. Scale bar: 8=175µm. Sample 220.

10, 11, 12. *Orbiculaforma kyklica* n. sp. Paratypes = 10=3054/17, 11=3054/21, 12=3054/8. Scale bar: 10=178µm, 11=156µm, 12=163µm. Sample 232, 231, 223.

PLATE 15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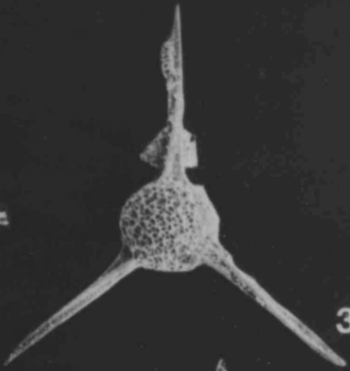
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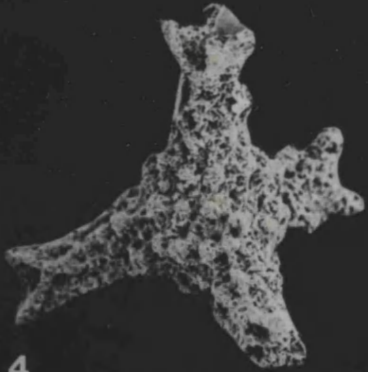
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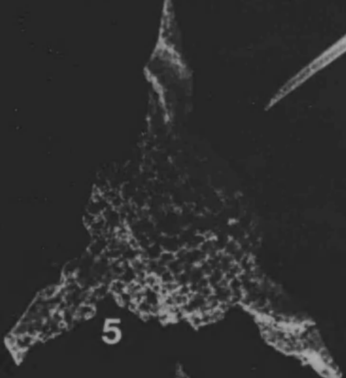
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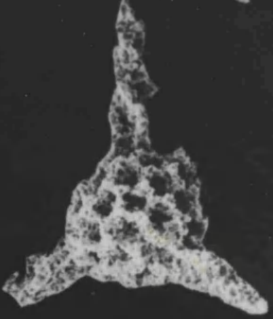
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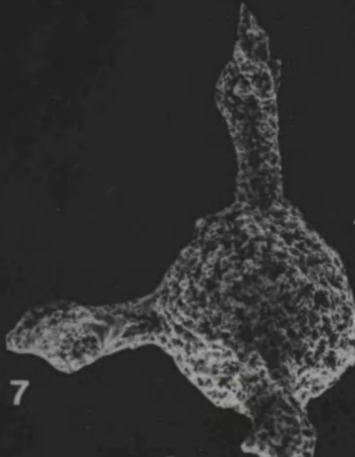
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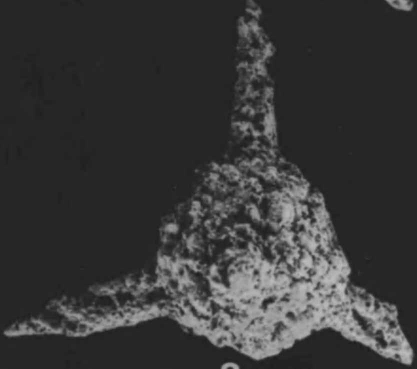
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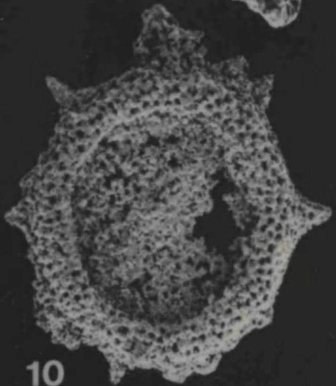
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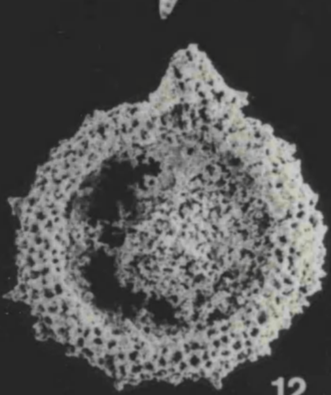
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PLATE 16

Explanation of Plate 16

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1. *Bipedis* sp. A 1=3074/8. Scale bar: 1=161µm. Sample 220, 246, 223.

2, 3, 4. Spumellaria gen. and sp. indet. A 2=3073/3, 3=3057/14, 4=3073/13. Scale bar: 2=178µm, 3=183µm, 4=162µm. Sample 246, 223, 232, 231.

5. *Vinassaspongus* sp. B 5=3026/1. Scale bar: 5=150µm. Sample 223.

6. *Natraglia* sp. A 6=3914/13. Scale bar: 6=204µm. Sample Tr 90 041s.

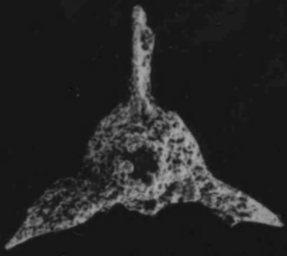
7, 10. *Spongoserrula*? sp. A 7=3074/28, 10=3074/28. Scale bar: 7=171µm, 10=82µm. Sample 246, 232.

8, 9. *Spongostylus carnicus* Kozur and Mostler, 1979 8=3251/7, 9=3251/30.Scale bar: 8=198µm, 9=189µm. Sample 223, 232, 216-217-218.

11, 12. *Heliosoma* sp. aff. *H. mocki* Kozur and Mostler, 1979 11=3054/23, 12=3026/12. Scale bar: 11=87µm, 12=65µm. Sample 246, 232, 223, 220.

13. *Archaeocenosphaera*? sp. A 13=3747/19. Scale bar: 13=189µm . Sample 216-217-218, 232, 223, 220.

PLATE 16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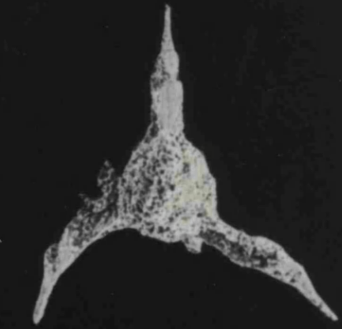
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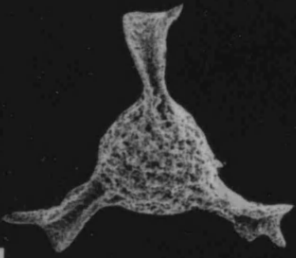
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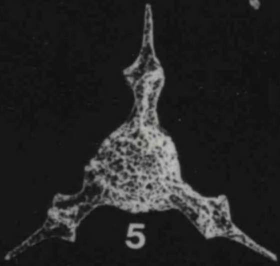
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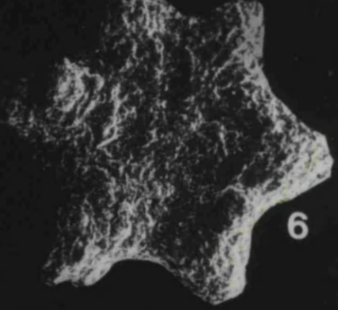
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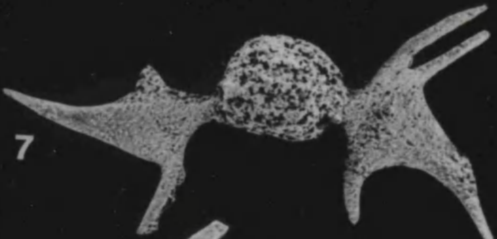
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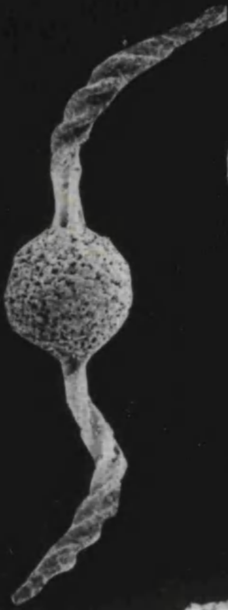
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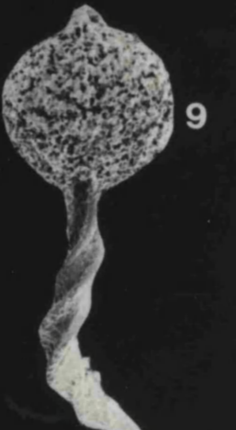
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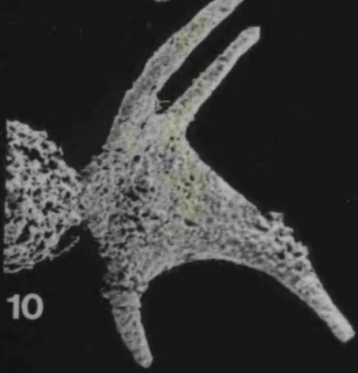
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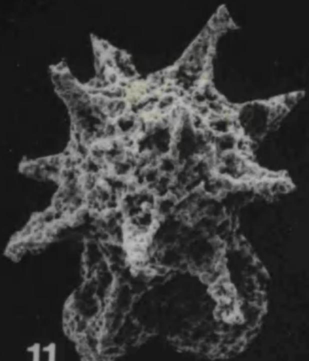
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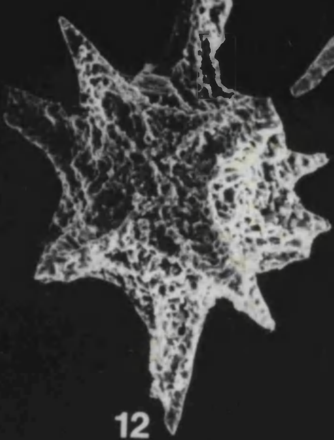
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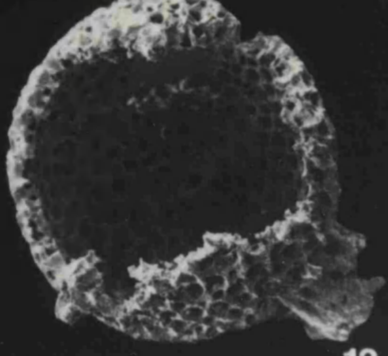
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PLATE 17

Explanation of Plate 17

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 2, 4. *Palaeosaturnalis raridenticulatus* Kozur and Mostler, 1981 1=3027/30, 2=3056/5, 4=3276/1.Scale bar: 1=207µm, 2=151µm, 4=100µm. Sample 232, 231, 223, 246, 239, 216-217-218.

3, 5, 6. *Palaeosaturnalis latiannulatus* Kozur and Mostler, 1983 3=3074/2, 5=3074/1, 6=3074/2. Scale bar: 3=162µm, 5=160µm, 6=98µm. Sample 223, 231.

7, 8, 9, 10. *Pseudosaturniforma carnica* Kozur and Mostler, 1979 7=3020/27, 8=3057/2, 9=3020/28, 10=3020/26. Scale bar: 7=92µm, 8=79µm, 9=100µm, 10=62µm. Sample 232.

11. *Triarcella sulovensis* Kozur and Mostler, 1981 113747/9. Scale bar: 11=59µm. Sample 232, 246, 223.

PLATE 17

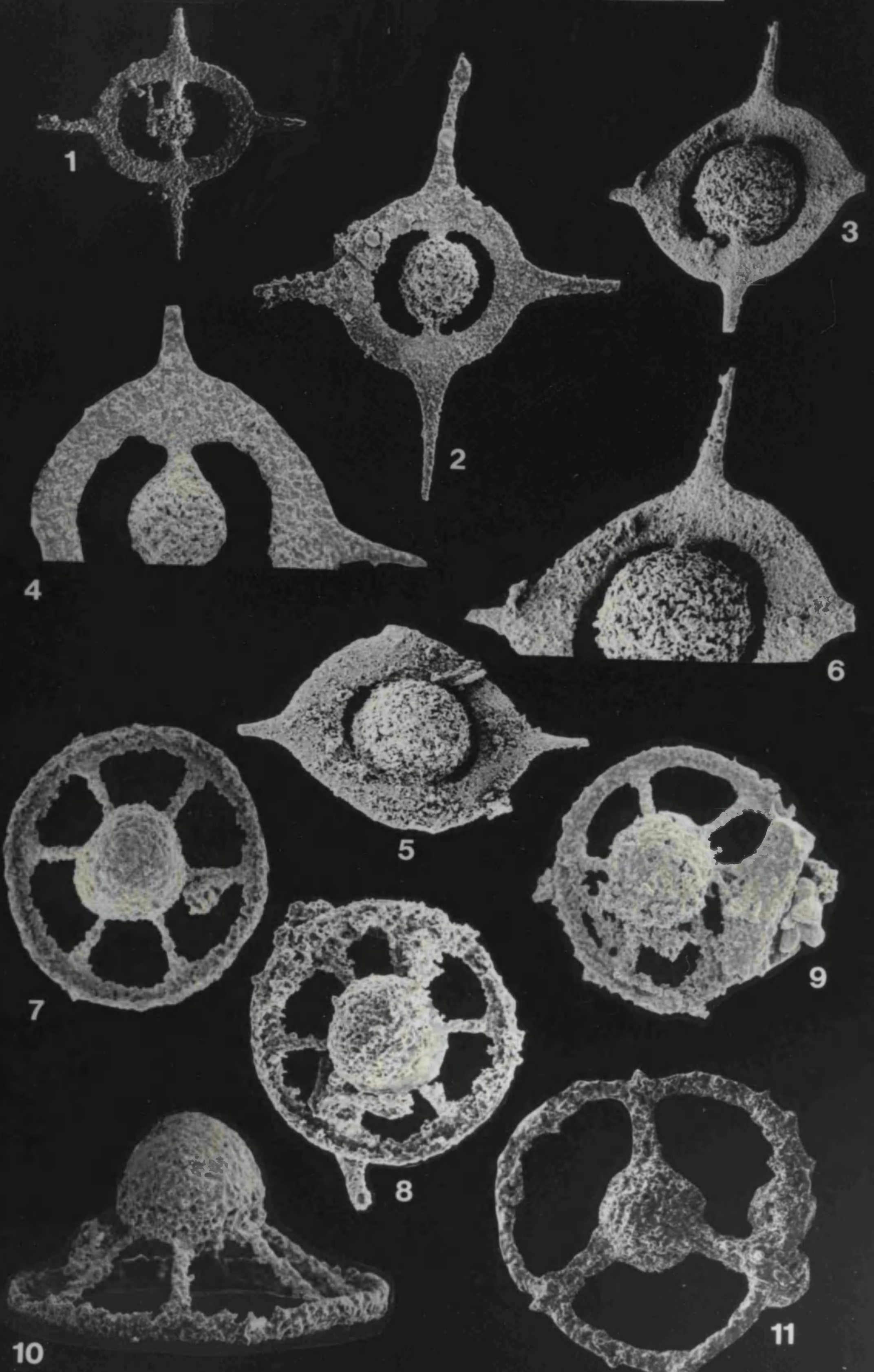


PLATE 18

Explanation of Plate 18

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

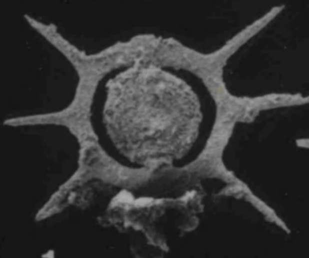
1. *Palaeosaturnalis burnensis* Blome, 1984 1=3020/30. Scale bar: 1=308µm. Sample 232, 228, 224, 216-217-218.

2, 7. *Palaeosaturnalis* sp. A 2=3020/33, 7=3020/33. Scale bar: 2=200µm, 7=102µm. Sample 232.

3, 5, 6, 8, 9. *Palaeosaturnalis supleensis* Blome, 1984 3=3056/12, 5=3056/7, 6=3056/13, 8=3056/7, 9=3056/13. Scale bar: 3=143µm, 5=139µm, 6=189µm, 8=78µm, 9=98µm. Sample 232, 246, 223.

4, 10. *Palaeosaturnalis ovalis* n. sp. Holotype = 4=3056/11, 10=3056/11. Scale bar: 4=200µm, 10=81µm. Sample 232.

PLATE 18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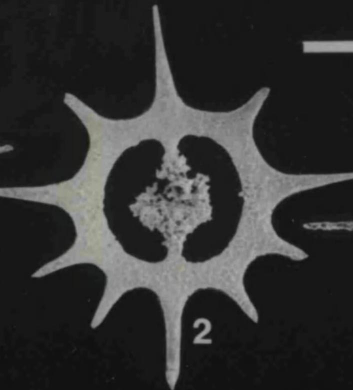
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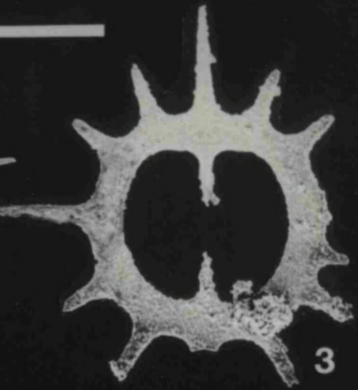
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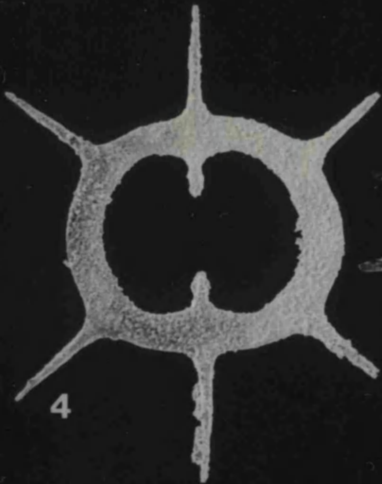
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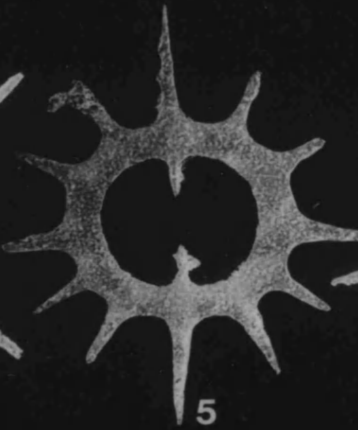
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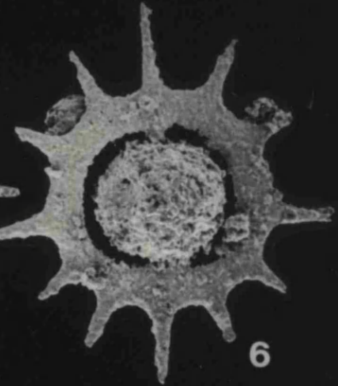
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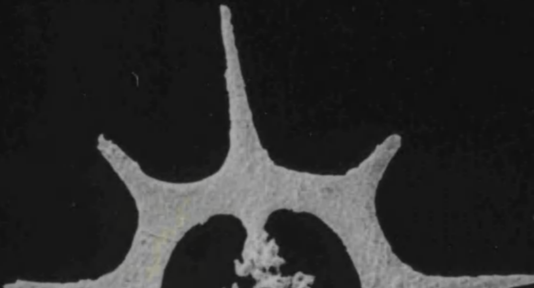
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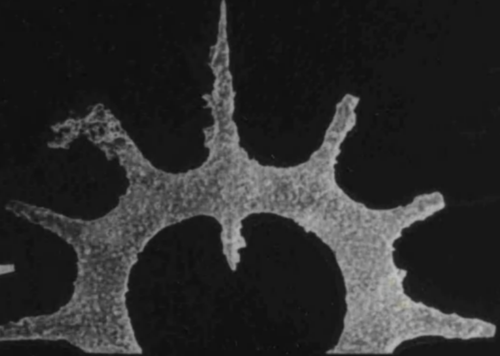
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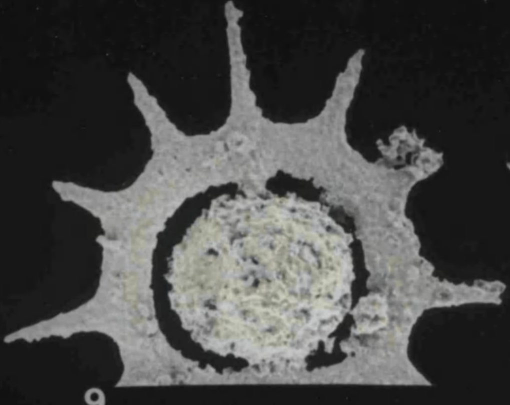
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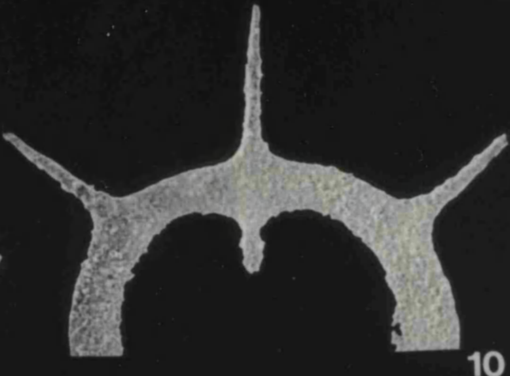
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PLATE 19

Explanation of Plate 19

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 10. *Palaeosaturnalis* sp. aff. *P. liassicus* Kozur and Mostler, 1990 1=3056/19, 10=3056/19. Scale bar: 1=200µm, 10=112µm. Sample 232, 246.

2. *Palaeosaturnalis* sp. A 2=3056/18. Scale bar: 2=209µm. Sample 232.

3. *Palaeosaturnalis burnensis* Blome, 1984 3=3056/9. Scale bar: 3=322µm. Sample 232, 228, 224, 216-217-218.

4, 11. *Palaeosaturnalis* sp. B, 4=3074/4, 11=3074/4. Scale bar: 4=126µm, 11=62µm. Sample 232.

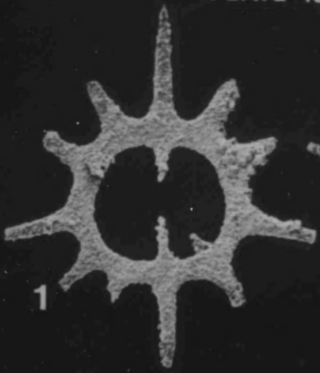
5, 9. *Palaeosaturnalis* sp. D, 5=3027/31, 9=3020/22. Scale bar: 5=202µm, 9=158µm. Sample 232.

6. *Palaeosaturnalis* sp. C, 6=3027/28. Scale bar: 6=165µm. Sample 232, 246.

7. *Palaeosaturnalis* sp. aff. *P. mocki* Kozur and Mostler, 1983 7=3020/25. Scale bar: 7=139µm. Sample 232.

8. *Palaeosaturnalis* sp. aff. *P. usitatus* Blome, 1984 8=3027/27. Scale bar : 8=171µm. Sample 232.

PLATE 19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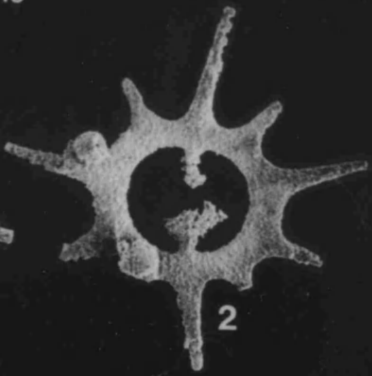
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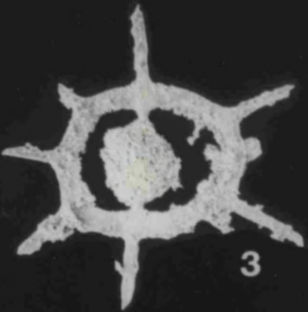
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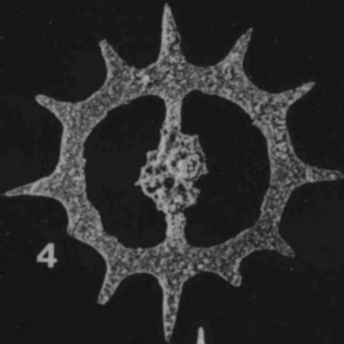
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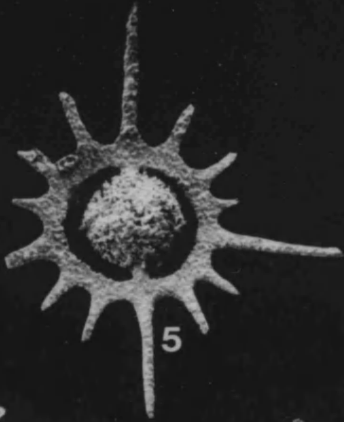
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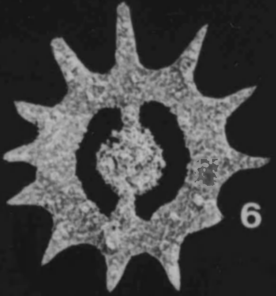
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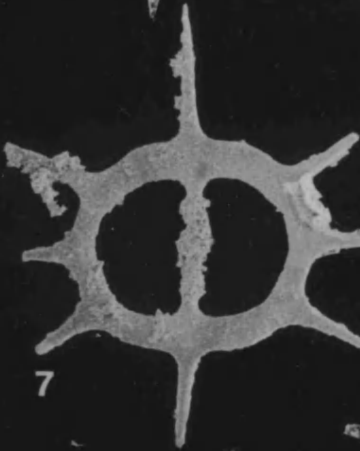
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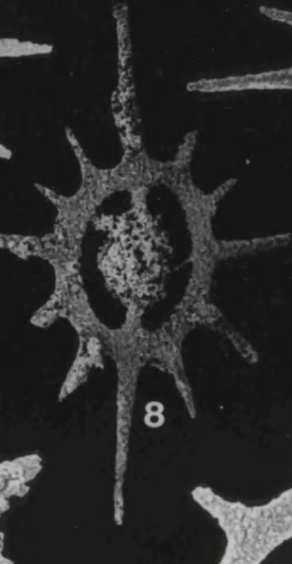
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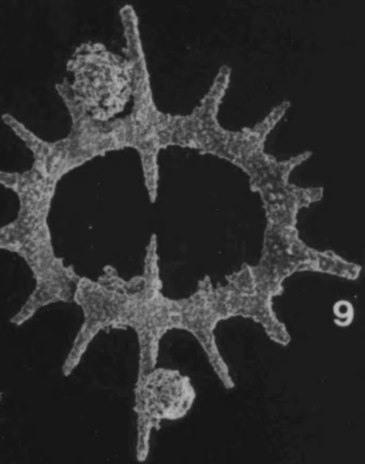
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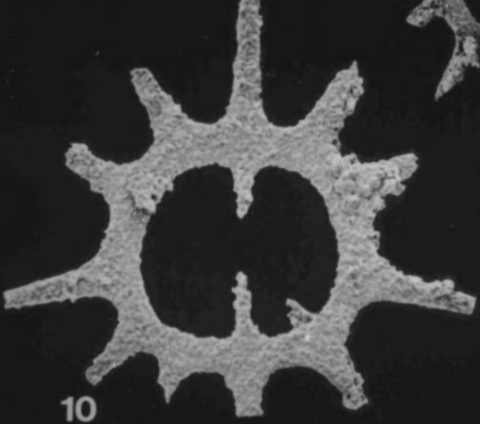
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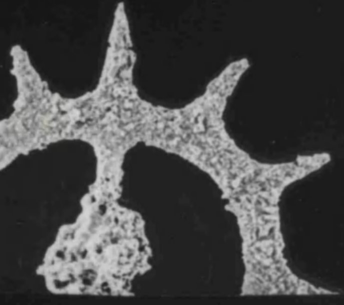
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PLATE 20

Explanation of Plate 20

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 10. *Pseudoheliodiscus carteri* n. sp. Holotype = 1=3020/22, 10=3020/22. Scale bar: 1=208µm, 10=120µm. Sample 232.

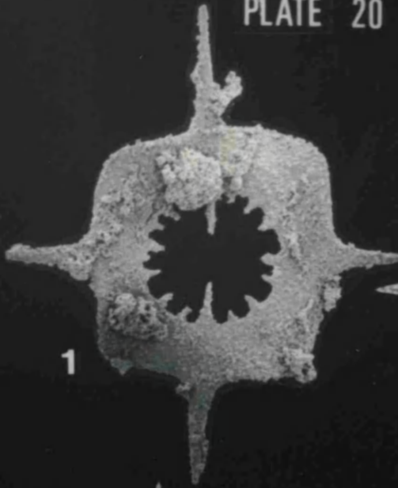
2, 3. *Pseudoheliodiscus carteri* n. sp. Paratypes = 2=3056/6, 3=3056/17. Scale bar: 2=193µm, 3=200µm. Sample 232.

5. ?*Stauracanthocircus tozeri* n. sp. Holotype = 5=3056/2. Scale bar: 5=202µm. Sample 232.

4, 6, 8, 9. ?*Stauracanthocircus tozeri* n. sp. Paratypes = 4=3027/2, 6=3020/20, 8=3276/3, 9=3056/21 Scale bar: 4=200µm, 6=200µm, 8=178µm, 9=162µm. Sample 232.

7, 11. *Pseudoheliodiscus* sp. A 7=3056/16, 11=3056/10. Scale bar: 7=188µm, 11=143µm. Sample 232.

PLATE 20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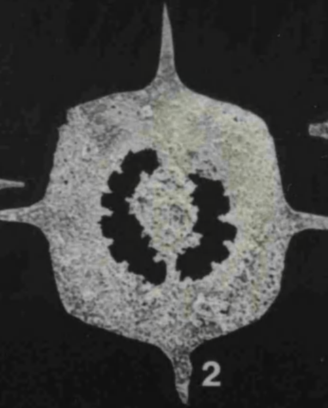
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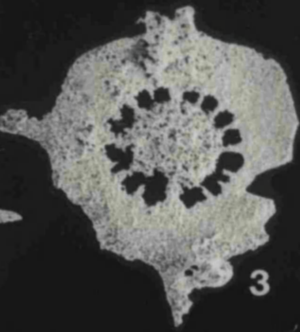
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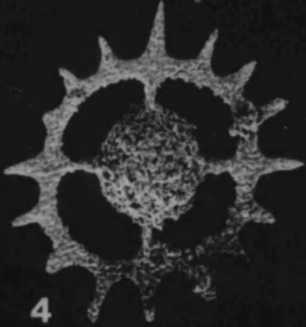
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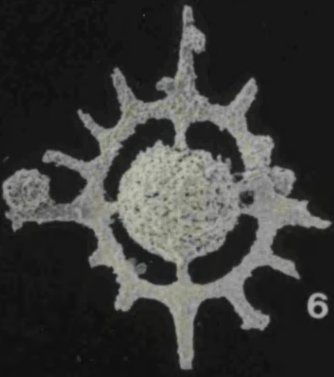
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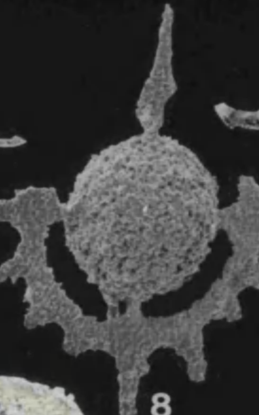
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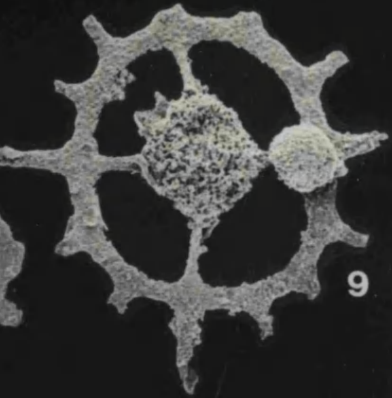
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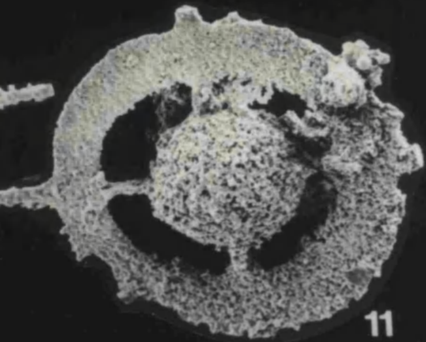
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PLATE 21

Explanation of Plate 21

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 3. *Kozurastrum* sp. A 1=3208/23, 3=3208/21. Scale bar: 1=300μm, 3=324μm. Sample 220, 224.

2. *Kozurastrum sandspitense* Blome, 1984 2=3208/16. Scale bar: 2=219μm. Sample 220, 224.

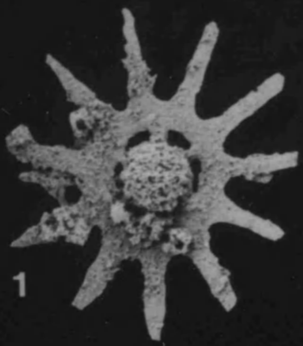
4, 5, 6, 9. *Kozurastrum* sp. aff. *K. sandspitense* Blome, 1984 4=3208/22, 5=3208/18, 6=3208/17, 9=3768/1. Scale bar: 4=212μm, 5=208μm, 6=218μm, 9=150μm. Sample Tr1, 220, 224.

7, 8. *Kozurastrum beatiense* Carter, 1993 7=3208/13, 8=3208/15. Scale bar: 7=176μm, 8=182μm. Sample 220, 224.

10. *Kozuastrum* sp. B 10=3768/3. Scale bar: 10=139μm Sample Tr1, 224.

11. *Kozurastrum* sp. C 11=3768/2. Scale bar: 11=163μm. Sample Tr1, 224

PLATE 21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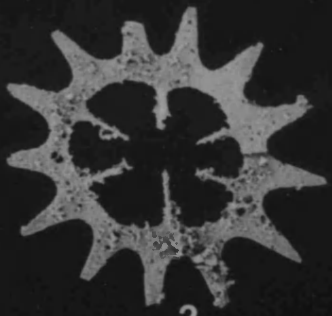
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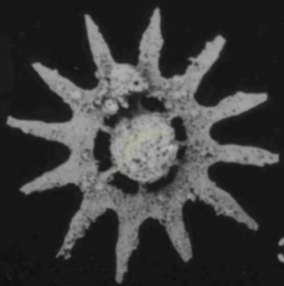
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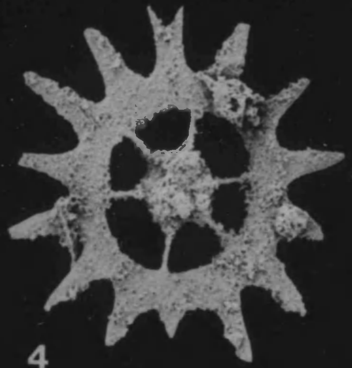
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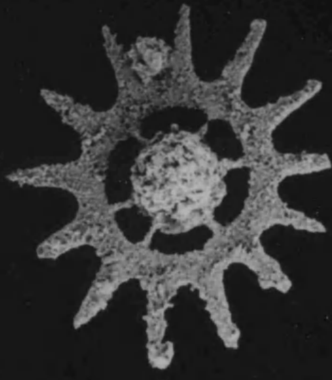
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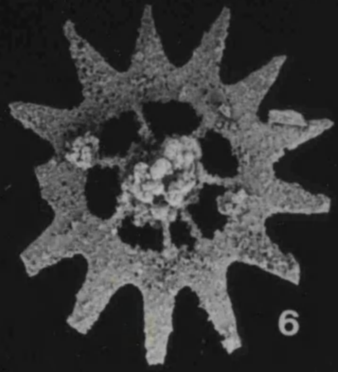
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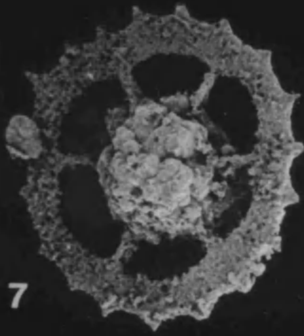
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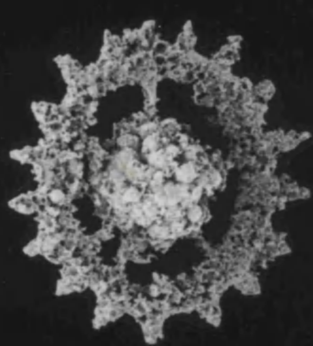
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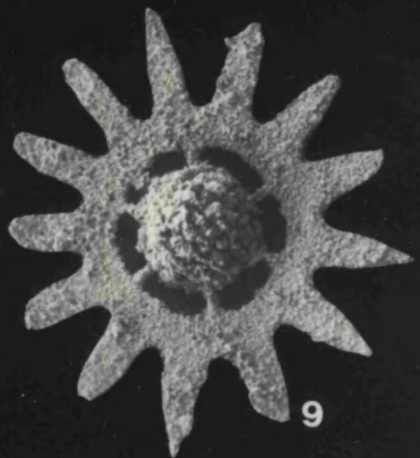
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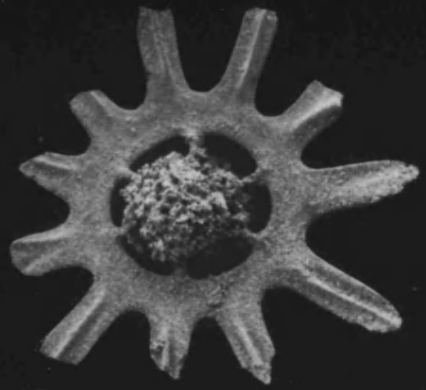
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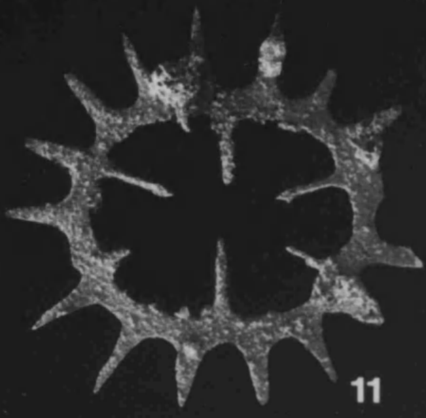
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PLATE 22

Explanation of Plate 22

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 5. ?*Syringocapsa* sp. A 1=3053/26, 5=3053/26. Scale bar: 1=163µm, 5=82µm. Sample 232.

2, 3, 4, 7. *Syringocapsa batodes* De Wever, 1979 2=3053/26, 3=3053/28, 4=3053/25, 7=3053/28. Scale bar: 2=165µm, 3=155µm, 4=165µm, 7=89µm. Sample 232, 246, 239, 223, 216-217-218.

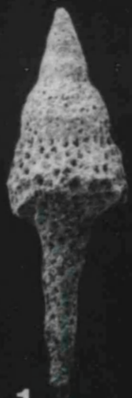
8, 9, 10. *Syringocapsa batodes* De Wever, 1979 8=3053/27, 9=3053/23, 10=3251/14. Scale bar: 8=94µm, 9=87µm, 10=92µm. Sample 232, 246, 239, 223, 216-217-218.

6. *Diblochras* sp. A 6=3053/31. Scale bar: 6=158µm. Sample 232, 246, 223.

11. *Syringocapsa* sp. aff. *S. batodes* De Wever, 1979 11=3020/3. Scale bar: 11=87µm. Sample 232.

12. ?*Diblochras* sp. B 12=3073/36. Scale bar: 12=147µm. Sample 246.

PLATE 22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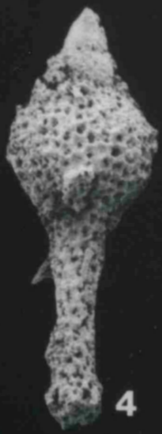
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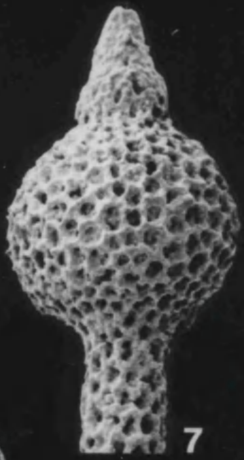
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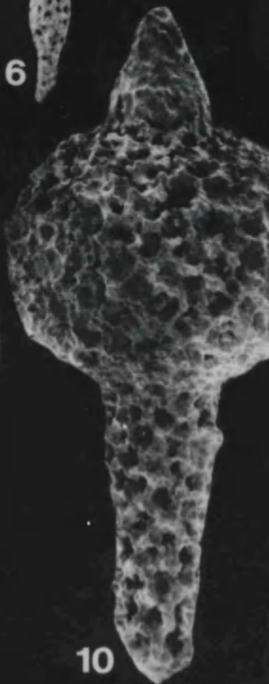
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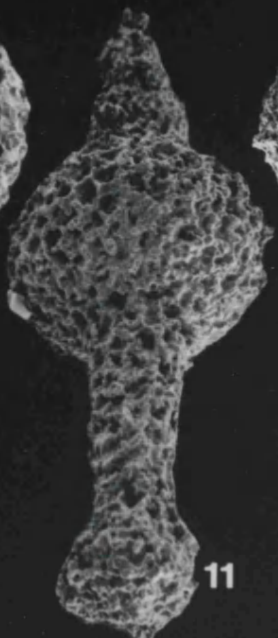
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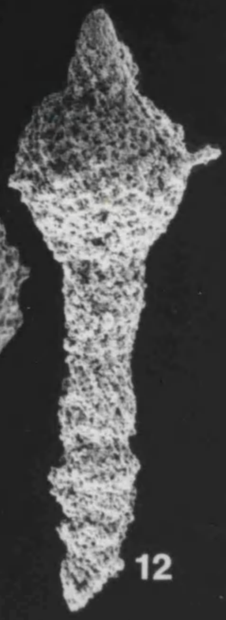
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PLATE 23

Explanation of Plate 23

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 3. *Bipedis* sp. A, 1=3101/3, 3=3074/9. Scale bar: 1=181μm, 3=162μm. Sample Sample 220, 246, 223.

2, 6. *Zhamojdasphaera? latispinosa* Kozur and Mostler, 1979 2=3074/6, 6=3074/6. Scale bar: 2=165μm, 6=110μm. Sample 246.

4, 5. *Karnospongella bispinosa* Kozur and Mostler, 1981 4=3074/10, 5=3074/10. Scale bar: 4=162μm, 5=85μm. Sample 246, 231, 232.

7. *Xiphotheca* sp. aff. *X. longa* Kozur and Mostler, 1981 7=3045/19. Scale bar: 7=158μm. Sample 232, 223.

8. *Xiphotheca* sp. A 8=3073/1. Scale bar: 8=145μm. Sample 246, 233-234, 223.

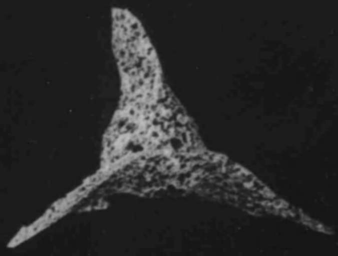
9. *Xiphotheca* sp. B 9=3045/15. Scale bar: 9=135μm. Sample 232, 223.

10, 11. *Xiphotheca longa* Kozur and Mostler, 1981 10=3045/20, 11=3045/22. Scale bar: 10=148μm, 11=151μm. Sample 232, 223.

12,14. *Squinabolella? maxima* n. sp. Holotype = 12=3208/5 14=3208/5. Scale bar: 12=208μm, 14=154μm. Sample 220, 224.

13. *Squinabolella ? maxima* n. sp. Paratype = 13=3208/10. Scale bar: 13=195μm. Sample 220, 224.

PLATE 23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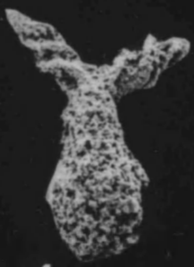
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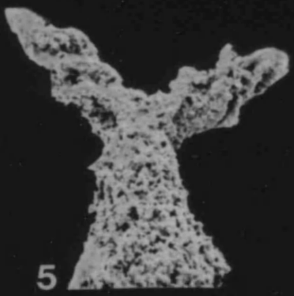
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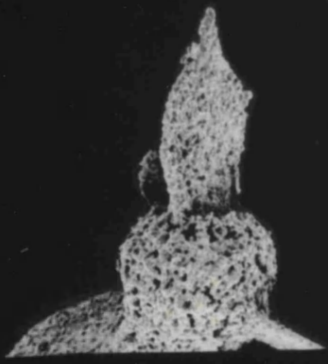
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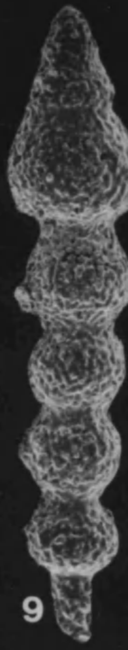
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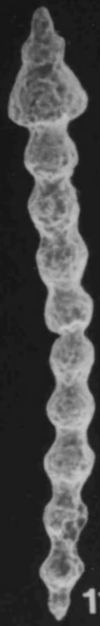
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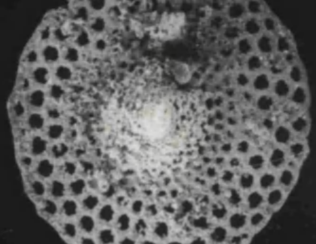
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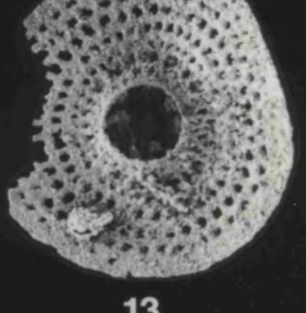
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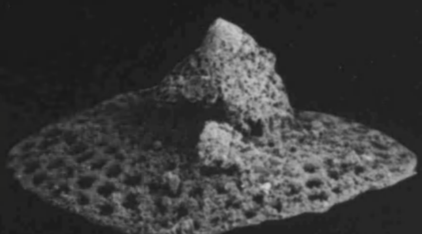
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PLATE 24

Explanation of Plate 24

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1, 3. *Deflandrecyrtium kozuri* n. sp. Holotype = 1=3208/11, 3=3208/12. Scale bar: 1=231μm, 3=179μm. Sample 220, 216-217-218.

2. ?*Deflandrecyrtium* sp. A 2=3208/1. Scale bar: 2=208μm. Sample 220.

4. *Squinabolella?* sp. aff. *S. trispinosa* Carter, 1993 4=3225/1. Scale bar: 4=157μm. Sample 231.

5. *Squinabolella* sp. aff. *S. causia,* Carter, 1993 5=3747/25. Scale bar: 5=149μm. Sample 224.

6. *Bulbocyrtium* sp. A 6=3100/12. Scale bar: 6=178μm. Sample 246, 232, 231, 223.

9. *Deflandrecyrtium? rhaetica n.* sp. Holotype = 9=3208/7. Scale bar: 9=175μm. Sample 220.

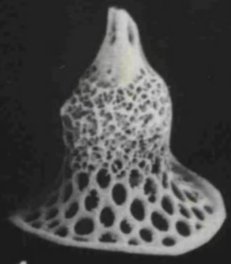
7, 12. *Deflandrecyrtium? rhaetica n.* sp. Paratypes = 7=3208/2, 12=3208/3. Scale bar: 7=172μm, 12=172μm. Sample 220.

8. *Deflandrecyrtium* sp. B 8=3208/8. Scale bar: 8=88μm. Sample 220.

10. *Bulbocyrtium reticulkatum* Kozur and Mostler, 1981 10=3015/20. Scale bar: 10=100μm. Sample 232.

11. *Squinabolella?* sp. aff. *S. desrochersi* Carter, 1993 11=3015/18. Scale bar: 11=72μm. Sample 232, 223.

PLATE 24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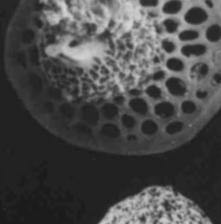
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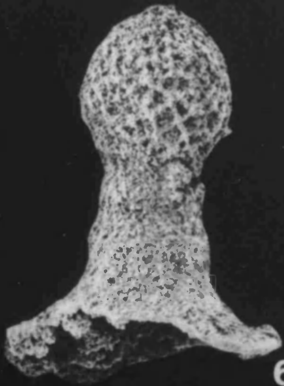
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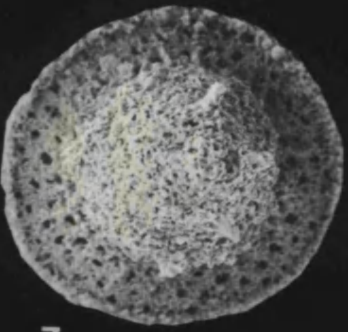
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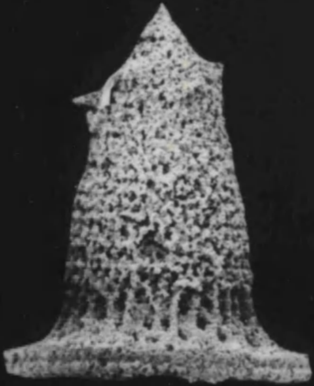
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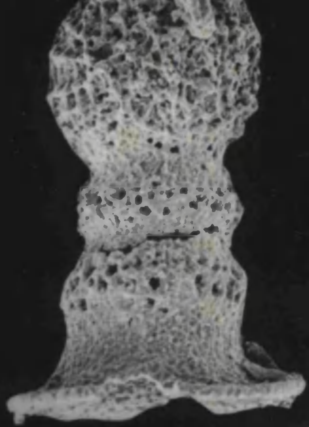
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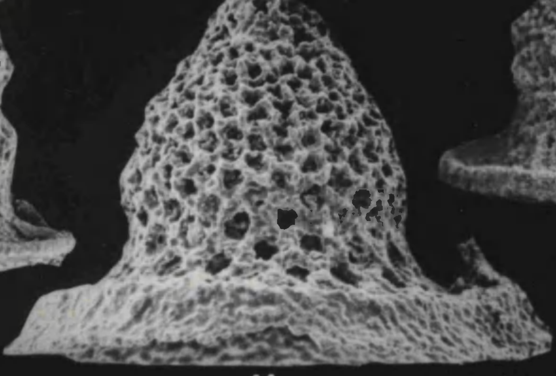
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PLATE 25

Explanation of Plate 25

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1. *?Entactinosphaera* sp. A 1=3054/15. Scale bar: 1=200µm. Sample 232, 223,

2, 3. *?Entacinosphaera* sp. B 2=3054/6, 3=3251/8. Scale bar: 2=202µm, 3=196µm. Sample 223, 246, 231.

4, 5. *Veghia* sp. aff. *V. goestlingensis* Kozur and Mostler, 1981 4=3100/9, 5=3100/9. Scale bar: 4=84µm, 5=84µm. Sample 220.

6. *Bulbocyrtium reticulatum* Kozur and Mostler, 1981 6=3015/21. Scale bar: 6=90µm. Sample 232.

7. *Veghia sulovensis* Kozur and Mostler, 1981 7=3100/17. Scale bar: 7=89µm. Sample 246.

8. *Tirodella goestlingensis* Kozur and Mostler, 1981 8=3057/5. Scale bar: 8=98µm. Sample 232.

9, 10. *Pararuesticyrtium?* sp. A 9=3015/19, 10=3100/2. Scale bar: 9=91µm, 10=89µm. Sample 232, 223, 220.

11. *Wuranella carnica* Kozur and Mostler, 1981 11=3074/8. Scale bar: 11=93µm. Sample 246.

PLATE 25

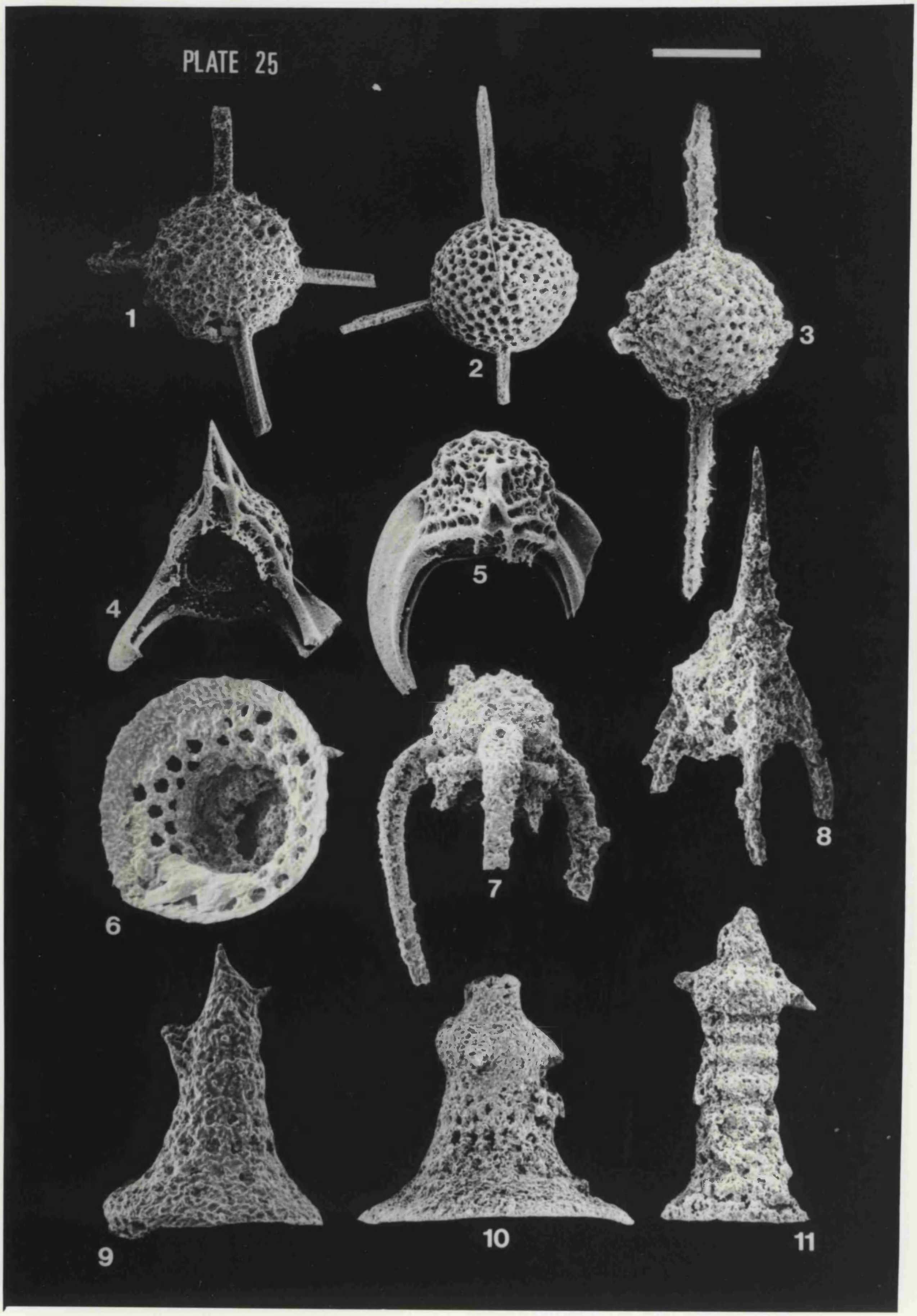


PLATE 26

Explanation of Plate 26

Scanning electron micrographs of Late Triassic radiolarians from the Aitutu Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures. If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Figure numbers in **bold** represent biostratigraphically important species.

1. *Canoptum* sp. A 1=3908/16. Scale bar: 1=100 µm. Sample 223, 209 (a), 205.

2, 7, 12. *Canoptum triassicum* Yao, 1982 2=3608/21, 7=3251/29, 12=3073/18. Scale bar: 2=125µm, 7=65µm, 12=63µm. Sample 231, 246, 241, 239, 233-2343, 232, 220, 216-217-218, 211.

3. *Corum perfectum* Blome, 1984 3=3073/31. Scale bar: 3=145µm. Sample 246.

4. Nassellarian gen. idet. and sp. indet. B 4=3057/1. Scale bar: 4=78µm. Sample 232.

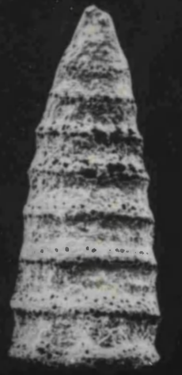
5, 6. *Pachus longiquus* Blome, 1984 5=3026/28, 6=3057/7. Scale bar: 5=87µm, 6=77µm. Sample 232, 223.

8. *Triassocampe*? sp. aff. *T. scalaris* Dumitrica, Kozur and Mostler, 1980 8=3747/27. Scale bar: 8=68µm. Sample 232.

9, 10. Nassellarian gen. idet. and sp. indet. A 9=3073/14, 10=3073/34. Scale bar: 9=76µm, 10=82µm. Sample 246.

11. *Corum regium* Blome, 1984 11=3026/31. Scale bar: 84µm. Sample 246.

PLATE 26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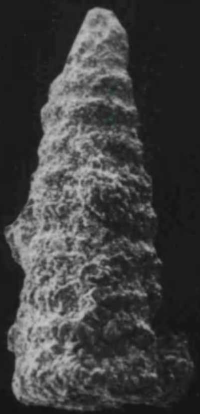
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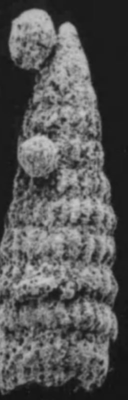
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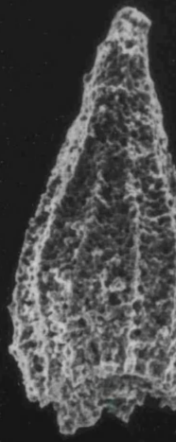
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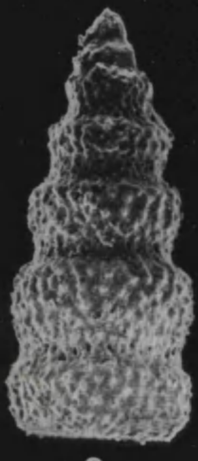
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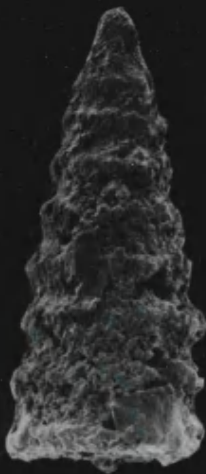
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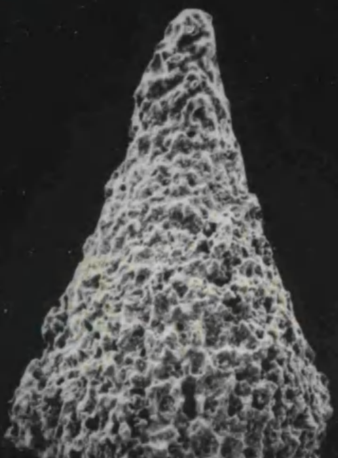
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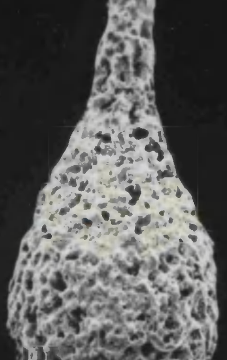
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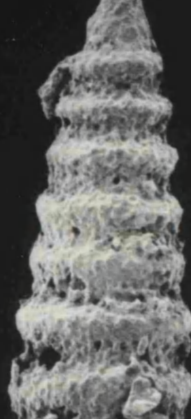
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PLATE 27

Explanation of Plate 27

Scanning electron micrographs of Early Jurassic radiolarians from theWai Luli Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures.If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Species with figure number marked in **bold** are biostratigraphically significant to this study.

1, 2. *Bistarkum regidium* Yeh, 1987 1=3608/22/, 2=3909/33. Scale bar: 1=175µm, 2=200µm. Sample Tr 90 009s, Tr 90 010s, Tr 90 019s, Tr 90 038s.

3. ?*Tetratrabs* sp. A 3=3914/2. Scale bar: 3=140µm. Sample Tr 90 002s, Tr 90 009s, Tr 90 010s.

4. *Archaeocenosphaera*? sp. A 4=3908/2. Scale bar: 4=76µm. Sample Tr 90 017.1s.

5. ?*Perispheridium* sp. A 5=3908/25. Scale bar: 5=76µm . Sample Tr 90 010s.

6. *Paronaella grahamensis* Carter, 1988 6=33608/28. Scale bar: 6=200µm. Sample Tr 90 001s, Tr 90 002s, Tr 90 003s, Tr 90 004s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 018s, Tr 90 019s, Tr 90 025s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s.

9. *Praeconocaryoma* sp. A 9=3909/19. Scale bar: 9=120µm. Sample Tr 90 001s, Tr 90 002s, Tr 90 009s, Tr 90 017s, Tr 90 017.1s, Tr 90 018s, Tr 90 038s.

7, 8. *Praeconocaryoma* sp. B 7=33908/3, 8=3909/12. Scale bar: 7=62µm, 8=60µm. Sample Tr 90 001s, Tr 90 003s, Tr 90 004s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s.

10. *Pseudoaulophacus*? sp. A 10=3909/28. Scale bar: 10=150µm. Sample Tr 90 002s, Tr 90 003s, Tr 90 009s, Tr 90 010s, Tr 90 012s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s.

11. *Crucella*? sp. A 11=3909/24. Scale bar: 11=150µm. Sample Tr 90 003s, Tr 90 004s, Tr 90 009s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 016s, Tr 90 017.2s, Tr 90 019s, Tr 90 025s, Tr 90 039s.

PLATE 27

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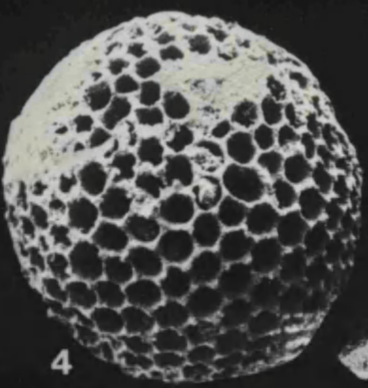

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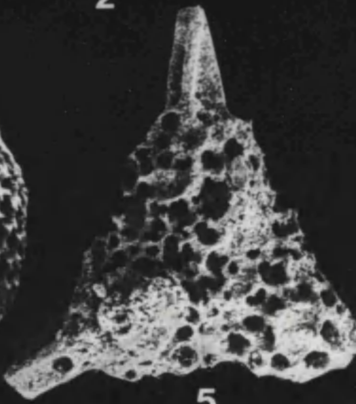

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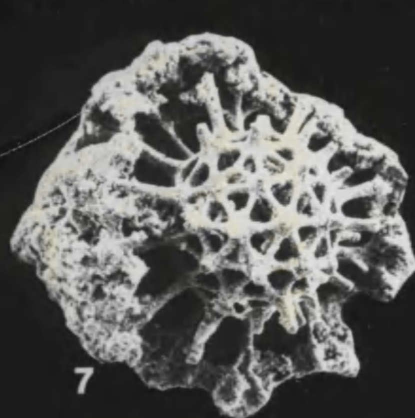

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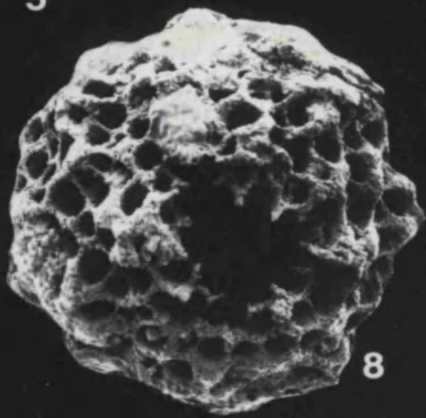

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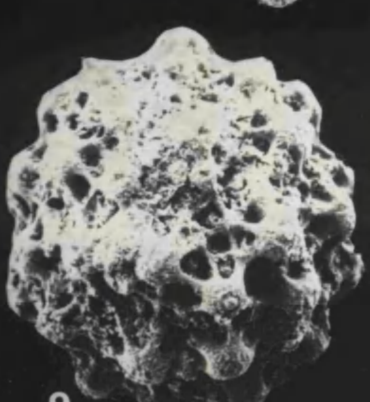

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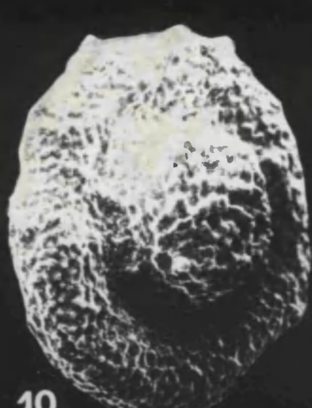

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PLATE 28

Explanation of Plate 28

Scanning electron micrographs of Early Jurassic radiolarians from theWai Luli Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures.If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Species with figure number marked in **bold** are biostratigraphically significant to this study.

1, 2, 3. *Canoptum anulatum* Pessagno and Poisson, 1981 1=3909/22, 2=3908/7, 3=3909/32. Scale bar: 1=150µm, 2=175µm, 3=225µm. Sample Tr 90 001s, Tr 90 002s, Tr 90 003s, Tr 90 004s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 039s, Tr 90 040s, Tr 90 006s, Tr 90 025s.

4. *Parahsuum ovale* Hori and Yao, 1988 4=3908/19. Scale bar: 4=85µm. Sample Tr 90 025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s.

5, 8. ?*Parahsuum* sp. aff. *P. simplum* Yao, 1982 5=3908/33, 8=3908/18. Scale bar: 5=80µm , 8=82µm. Sample Tr 90 025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s.

6, 7. ?*Parahsuum* sp. aff. *P. simplum* Yao, 1982 6=3908/38, 7=3909/35. Scale bar: 6=88µm, 7=68µm. Sample Tr 90 025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 19s, Tr 90 033s.

9, 10, 11, 12 ?*Parahsuum* sp. aff. *P. simplum* Yao, 1982 9=3909/7, 10=3909/4, 11=3909/9, 12=3908/32. Scale bar: 9=60µm, 10=60µm, 11=60µm, 12=85µm. Sample Tr 90 025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s.

13, 14. *Pseudoristola obesa* Yeh, 1987 13=3908/28, 14=3908/28. Scale bar: 13=92µm, 14=65µm. Sample Tr 90 009s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 038s, Tr 90 039s.

PLATE 28


1


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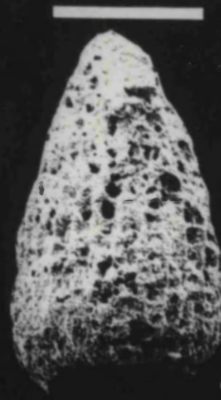
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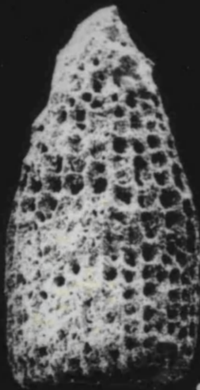
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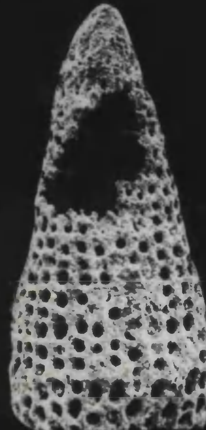
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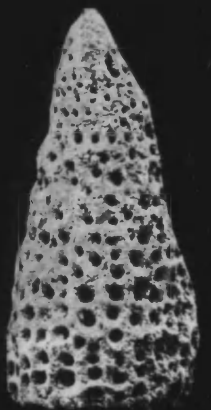
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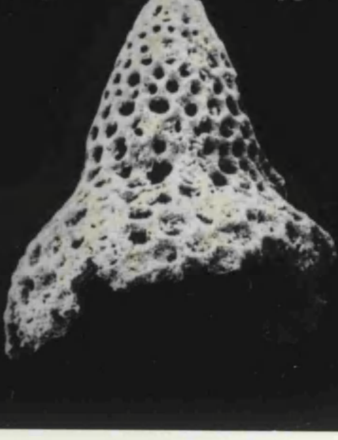
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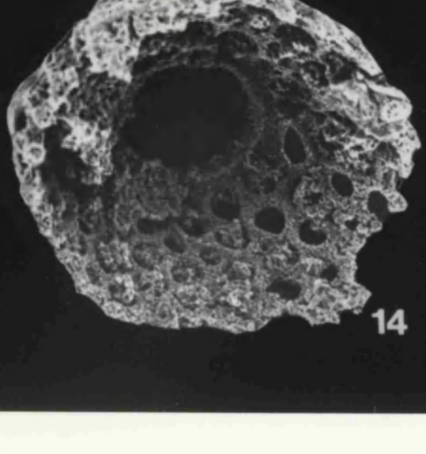
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PLATE 29

Explanation of Plate 29

Scanning electron micrographs of Early Jurassic radiolarians from theWai Luli Formation, Timor, Indonesia. Scale bar (upper right) is used for all figures.If the same specimen is figured more than once then the same catalogue number is used with a change in the corresponding figure number. Species with figure number marked in **bold** are biostratigraphically significant to this study.

1. Nassellarian gen. and sp. indet C Scale bar: 1=87µm. Sample Tr 90 025s.

2, 3. ?*Maudia* sp. A 2=3914/11, 3=3909/29. Scale bar: 2=230µm, 3=235µm. Sample Tr 90 002s, Tr 90 004s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 033s, Tr 90 038s, Tr 90 039s, Tr 90 040s.

4. ?*Maudia* sp. B 4=3909/16. Scale bar: 4=248µm. Sample Tr 90 003s, Tr 90 009s, Tr 90 038s, Tr 90 039s.

5. *Pseudoristola obesa* Yeh, 1987 5=3908/31. Scale bar: 5=88µm. Sample Tr 90 009s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 038s, Tr 90 039s.

6. *Pseudoristola* sp. A 6=3908/30. Scale bar: 6=80µm. Sample Tr 90 002s.

7, 8. *Pseudoristola* sp. aff. *P. megalobosa* Yeh, 1987 7=3909/25, 8=3909/23. Scale bar: 7=150µm, 8=160µm. Sample Tr 90 025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s.

9. *Archaeodictyomitra*? sp. A 9=3909/30. Scale bar: 9=95µm. Sample Tr 90 027s, Tr 90 001s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 016s, Tr 90 017.1s, Tr 90 017.2s, Tr 90 018s, Tr 90 038s.

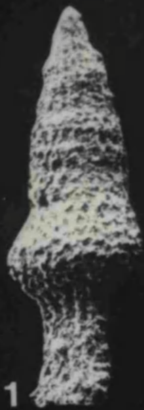
10. ?*Parahsuum* sp. aff. *P. simplum* Yao, 1982 10=3909/39. Scale bar: 10=60µm. Sample Tr 90 025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s.

11. ?*Parahsuum* sp. aff. *P. simplum* Yao, 1982 11=3909/37. Scale bar: 11=70µm. Sample Tr 90 025s, Tr 90 002s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 017s, Tr 90 017.2s, Tr 90 019s, Tr 90 033s.

12. *Pseudoristola obesa* Yeh, 1987 12=3908/26. Scale bar: 12=50µm. Sample Tr 90 009s, Tr 90 011s, Tr 90 012s, Tr 90 019s, Tr 90 033s, Tr 90 038s, Tr 90 039s.

13. *Orbiculiforma callosa* Yeh, 1987 13=3908/14. Scale bar: 13=150µm. Sample Tr 90 001s, Tr 90 002s, Tr 90 003s, Tr 90 009s, Tr 90 010s, Tr 90 011s, Tr 90 012s, Tr 90 015s, Tr 90 018s, Tr 90 019s, Tr 90 025s, Tr 90 033s, Tr 90 039s, Tr 90 040s.

PLATE 29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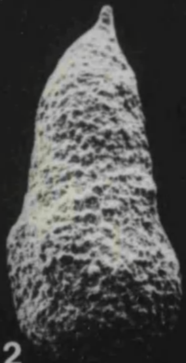
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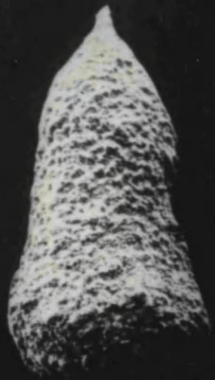
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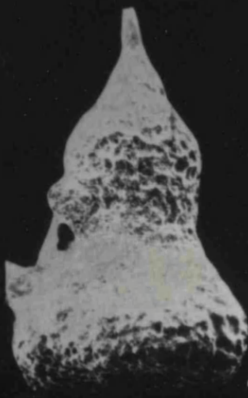
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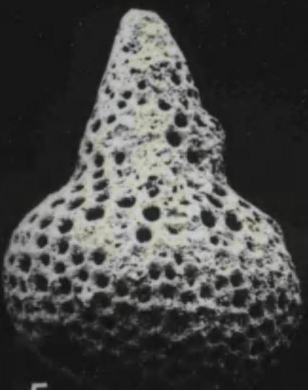
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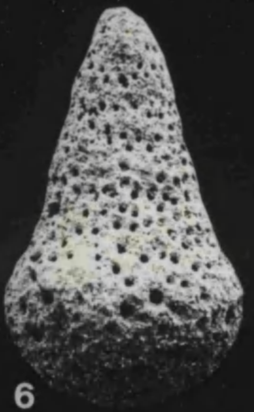
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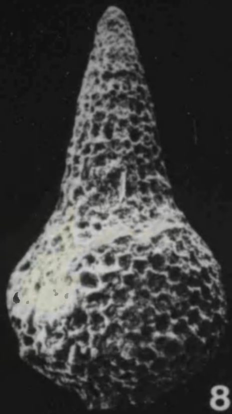
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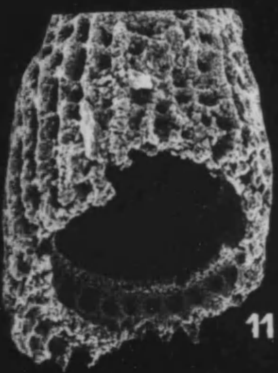
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