Early to Middle Paleozoic Conodonts from Thailand and Peninsular Malaysia

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Sachiko AGEMATSU

Contents

Abstract

Early to Middle Paleozoic (Early Ordovician to Early Devonian) conodont biostratigraphy and taxonomy have been investigated from Thailand and peninsular Malaysia. Totally 31 conodont zones are established in the Thong Pha Phum area (western Thailand), the Thung Song, Thung Wa, and Satun areas (southern peninsular Thailand), Tarutao Island (southern peninsular Thailand), and the Langkawi Islands in northern peninsular Malaysia. On Tarutao Island, the following seven zones are built up; the *Monocostodus sevierensis* range zone and the *M. sevierensis* - *Variabiloconus bassleri* interval zone, in ascending order, in the TAR 1 section; the *Rossodus manitouensis* range zone, the *R. manitouensis* - *Teriodon nakamurai* interval zone, the *T. nakamurai* - *V. bassleri* interval zone, Gen. et sp. Indet. 7 range zone, and Gen. et sp. Indet. 7 - *Colaptoconus floweri* interval zone, in ascending order, in the TAR 2 section. In the Thong Pha Phum area, four zones are established in the TPP section; the *Panderodus nogamii* - *Triangulodus brevibasis* interval zone, the *T. brevinasis* range zone, the *T. brevinasis* - *Drepanoistodus costatus* interval zone, and the *Plectodina onychodonta* assemblage zone, in ascending order. In the Thung Wa area, following two zones, the *Periodon aculeatus* range zone and the *Protopanderodus gradatus* range zone, are made up in the TUW 2 and TUW 1 sections, respectively. In the Thung Song area, the *P. nogamii* range zone is established in the TUS section. The following five zones are built up in the Satun area; the *Pygodus anserinus* range zone, the *Baltoniodus* sp. cf. *B. variabilis* range zone, the *Scabbardella altipes* - *Hamarodus europaeus* interval zone, and the *H. europaeus* range zone, in ascending order, in the ST 1 section; the *Ozarkodina excavata excavata* range zone in the ST 2 section. In the Langkawi Islands, the twelve zones are set up; the Gen. et sp. Indet. 13 range zone, the *D. costatus* range zone, the *D. costatus* - *P. nogamii* interval zone, the *B.* sp. cf. *B. variabilis* range zone, the Gen. et sp. Indet. 12 range zone, the *H. europaeus* range zone, the *Ozarkodina pennatus proceus* range zone, the *Dapsilodus obliquicostatus* range zone, the *Ozarkodina remscheidensis remscheidensis* range zone, and the *O. r. remscheidensis* - *Pseudooneotodus beckmanni* interval zone, in ascending order, in the LAN 1 section, and the *Cooperignathus aranda* range zone and the *Scolopodus quadratus* range zone, in ascending order, in the LAN 2 section.

Reconstructed sea-level curves of the study areas exhibit several characteristic transgression and regression events during the Ordovician to Silurian time. The late Tremadocian and earliest Middle Ordovician regressions are parallel to the global sea level falls, and late Arenigian to middle Darriwilian transgressions are compared with a regional sea level rise in the northern Gondwana. The glacio-eustatic sea-level changes, which are found in the most of the uppermost Ordovician sequences in the world, do not have a great influence to the depositional environment of the study areas. Correlations between the Ordovician conodonts from the study areas and those of the Australia, North and South China, North Atlantic, and North America suggest that the Early to Middle Ordovician conodont faunas from the study areas belong to the East Asia - Australasia Province and the Upper Ordovician conodonts have a close affinity with those of the North Atlantic Province. This most important faunal change took place in middle Darriwilian and was caused by a regional transgression in the marginal area of the northern Gondwana. The Caradocian conodont fauna from the study areas is compared with one of the typical conodont biofacies of the North Atlantic Province, which was distributed in the middle to high latitudes. Based on the paleogeographic correlation and the depositional environments, the historical geology of the study areas is interpreted as follows: the Lower to Middle Ordovician rocks in the study areas accumulated on a shelf of the Shan-Thai Block, which had been situated near Australia and North and South China in the low latitudes; the transgression of the northern Gondwana in late Arenigian to middle Darriwilian caused the faunal change of conodonts from the East Asia - Australasia fauna to the North Atlantic fauna; the Shan-Thai Block moved to the higher latitudes until Caradocian; the depositional environment of the study areas was maintained in a hemipelagic condition during Late Ordovician to Early Devonian.

Ninety five species belonging to 50 genera and 22 unidentified species of Early Ordovician to Early Devonian conodonts are described and illustrated.

Key words: biostratigraphy, conodonts, Early Devonian, Malaysia, Ordovician, Silurian, Thailand,

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1. INTRODUCTION

From tectonic and paleontological evidence presented in last 20 years, it has become clear that Asia is an aggregate of several allochthonous continental blocks. A majority of these blocks owe their origin to Gondwana, and had progressively divided and moved northward from the northern periphery of that vast continent (e.g., Metcalfe, 1999). The traces from the dispersion to accretion have been discussed in detail based chiefly on paleobiogeographic evidence from microfossils such as Radiolaria and Foraminifera (Metcalfe, 1991, 1996; Sashida et al., 1999). On the basis of the paleontological information, the first rifting events are thought to have begun in Late Devonian (e.g., Metcalfe et al., 1999).

The area which constitutes a part of the present-day Indochina and Malay Peninsula of Southeast Asia was originally a long and narrow continental piece of Gondwana and a basin that held thick carbonate and clastic sediments of Cambrian to Devonian age (e.g., Bunopas, 1992). These Paleozoic rocks are preserved in the several areas from northwestern Thailand to West Malaysia and yield various macrofossils such as trilobites, nautiloids, gastropods, and brachiopods (Kobayashi, 1964; Hamada et al., 1975; Hahn and Siebenhüner, 1982). Early to Middle Paleozoic fossils were firstly described in 1950s (Kobayashi, 1964) and have been studied paleontologically since then (e.g., Kobayashi and Hamada, 1964b; Hamada, 1968; Igo and Koike, 1967, 1968; Stait and Burrett, 1984; Boucot et al., 1999). However, few biostratigraphic and paleobiogeographic studies have been undertaken. In this twenty years, the Early Paleozoic arrangement of ancient continents of Southeast Asia has been discussed (e.g., Metcalfe, 1988, 1999, 2002, 2005; Wang and Chen, 1995; Fortey and Cocks, 1998; Nicoll and Metcalfe, 2001), based on correlations with Australia and China suggested by these macrofossils. However, study of the Lower Paleozoic of Southeast Asia lags behind that of adjacent areas because there have been few fundamental biostratigraphic studies. Recently, advanced studies of Ordovician conodonts from the northern areas of Gondwana, including Australia and China, allow us to correlate with European and North American conodont faunas (e.g., Nicoll et al., 1993; Stait and Druce, 1993; Wang et al., 1996; Zhen et al., 1999, 2003a, b, c; Nicoll and Metcalfe, 2001). Conodonts have a high stratigraphic value throughout the Paleozoic and Triassic, and particularly Ordovician conodonts have been studied in detail because of the wide distribution of Ordovician rocks and a high diversity of Ordovician conodonts. In Thailand and peninsular Malaysia, numerous localities of conodonts have been reported previously from the widely exposed Lower to Middle Paleozoic sedimentary rocks. (Hamada et al., 1975; Hagan and Kemper, 1976).

Based on these facts, the objectives of this study are as follows; description of the Early to Middle Paleozoic conodonts from Thailand and peninsular Malaysia; establishment of the Lower to Middle Paleozoic conodont biostratigraphy; correlation of the conodont faunas from Thailand and Malaysia with those from the North American, North Atlantic, and other Gondwanan areas, and discussion on the paleobiogeography of Thailand and peninsular Malaysia; reconstruction of the depositional environments of the studied areas during the Early to Middle Paleozoic time.

2. METHODOLOGY

The studied areas are shown in Figure 1. One is located in the Thong Pha Phum area, western Thailand. The other areas lie in the Malay peninsula. The Thung Song, Thung Wa, and Satun areas and Tarutao Island are in southern peninsular Thailand, and the Langkawi Islands is in northern peninsular Malaysia. Field surveys were undertaken in July of 2001, February of 2002, and March, November, and December of 2003.

2.1 Field work

Totally ten sections are studied in the areas mentioned above; the Section TPP in the Thong Pha Phum area, the Setion TUS in the Thung Song area, the Section TUW 1 and TUW 2 in the Thung Wa area, the Section ST 1 and ST 2 in the Satun area, the Section TAR 1 and TAR 2 in Tarutao Island, and the Section LAN 1 and 2 in the Langkawi Islands. Two hundred and thirty two rock samples were collected from these sections. Intervals between each sampling horizon are 2 to 20 m in thickness. The sampling interval of the TAR 2 section in the Tarutao Island and the LAN 2 section in Langkawi Islands reaches several tens to more than 100 m due to the difficulties of access to the outcrops, which are located along a coast. Every rock sample averages 1.5 kg and 1 kg, respectively, and contains limestone or siliciclastics beds which cover less than 20 cm in thickness.

2.2 Laboratory methods

All the samples were treated with acid and heavy liquid to isolate conodonts. The rock samples were crushed into small pieces and weighted before soaked in acid. Limestone samples were treated with acetic acid at a concentration of 10 - 15 %, and siliciclastics samples were with hydrofluoric acid at a concentration of 5 %. Four days later, the residues were separated by sieves and dried out. The dried residues were subjected to sodium polytungstate treatment, which allows to separate residues containing conodont and heavy minerals with a gravity of more than 2.80. Conodonts were picked up from the residues and aligned on the SEM stubs. Photographs were taken using a Scanning Electron Microscope

(SEM) from lateral and oral or aboral angles of conodont element.

Limestone samples were thin sectioned and observed under a polarization microscope to investigate their components such as grains, matrices, fossils, and sedimentary structures. Limestone classification is followed that of Folk (1959, 1962).

3. TECTONIC AND GEOLOGIC FRAMEWORK

3.1 Thailand

It is the general consensus that the geology of Thailand comprises two principal continental blocks, the western Shan-Thai Block and the eastern Indochina Block (e.g., Bunopas, 1981). According to Bunopas (1981), these two blocks have a suture zone between them, which is bordered by the western Sukhothai and eastern Loei-Petchabun Fold belts. The area of the suture zone is called the Nan-Uttradit to the north and Sra (or Sa) Kaeo-Chanthaburi to the south (Figure 1).

The Shan-Thai and Indochina blocks are both elongate stable blocks with a Precambrian basement. Lower to Upper Paleozoic sequences are preserved on the Shan-Thai Block. Cambrian and Ordovician strata are siliciclastic and carbonate rocks, which are distributed in several restricted areas. The Middle to Upper Paleozoic sequence covers a more widespread area and includes terrestrial clastic and carbonate rocks. A characteristic rock of the Upper Paleozoic of this block is Upper Carboniferous to Lower Permian diamictite that is probably the result of glaciation (Bunopas, 1992). On the Indochina Block, Middle to Upper Paleozoic sequences are recognized. These sedimentary rocks are accompanied by some shallow marine faunas and floras suggesting a warm climate (Metcalfe, 1988). Bunopas (1992) suggested that the Paleozoic to Mesozoic sequences of these two blocks can be divided into the seven stratigraphic belts, BS-1 to BS-5 belonging to the Shan-Thai Block and BI-6 and BI-7 to the Indochina Block (Figure 1). The Thong Pha Phum area lies within BS-2, and the Thung Song, Thung Wa, and Satun areas and Tarutao Island are within BS-3. Lower to Middle Paleozoic sedimentary rocks in BS-2 and BS-3 are divided into the following main stratigraphic units by Bunopas (1992): Cambrian Tarutao Group, Ordovician Thung Song Group, Silurian to Carboniferous Thong Pha Phum Group, and Carboniferous Mae Hong Son Group (Figure 1).

The Thung Song Group was established in Nakhon Sri Thammarat province in the south of the peninsula (Javanaphet, 1969) and is officially applied to all Ordovician limestone in Thailand. Paleontology of this group has long been studied mainly in southern peninsular Thailand, due to abundant macrofossils (e.g., Kobayashi et al., 1964; Burton, 1967b; Hamada et al., 1975; Wongwanich et al., 1983; Stait and Burrett, 1984; Boucot et al., 1999). The Thong Pha Phum Group, which is mainly known in northwestern, western, and southern Thailand, exhibits various lithology, for example fossiliferous carbonate rocks in Kanchanaburi, western Thailand, and sandstone and shale in Mae Hong

Son, northwestern Thailand (Bunopas, 1992). Bunopas (1981) designated the Ordovician Thung Song Group in western Thailand as the Tha Manao Formation. He gave names, the Bo Phloi Formation and Mae Plung Shale, to the Silurian to Carboniferous sedimentary rocks in western Thailand. Wongwanich et al. (1990) subdivided the Thung Song Group in the Satun area, southern peninsular Thailand, into the Khao Ngiap Limestone, the Khao Nui Limestone, and the Pa Kae Formation, and the Silurian and Devonian rocks into the Wang Tong, Kuan Thung, and Pa Samed Formations, in ascending order. Cocks et al. (2005) reviewed the Paleozoic sequences distributed in the southern peninsular Thailand including Tarutao Island, and temporarily termed these rocks, in ascending order, the Thung Song Limestone, the Satun Shale, and the Pa Kae Formation. The compilation of the Lower to Middle Paleozoic sequence is complicated because a continuous section has not yet been observed, and only parts of these rocks are exposed locally. In this paper, I temporarily use "Thung Song Group" as the Ordovician limestone and "Thong Pha Phum Group" as the Silurian to Devonian rocks in Thailand.

3.2 Penincular Malaysia

Geological framework of peninsular Malaysia is also composed of two principal blocks, the Shan-Thai and Indochina Blocks (e.g., Bunopas, 1981; Metcalfe, 1999). Metcalfe (1999) summarized that the Nan-Uttradit to Sra Kaeo sutures in Thailand correspond to the Raub-Bentong suture in Malaysia, which separates these two continental blocks (Figure 1).

Lower to Middle Paleozoic rocks on the Shan-Thai Block in northwestern peninsular Malaysia are typically exposed on the Langkawi Islands, the central Kedah province, and the northern Perak province (Hamada et al., 1975; Jones, 1978). On the Langkawi Islands, the Lower to Middle Paleozoic rocks are grouped into the Cambrian Machinchang and the Ordovician to Devonian Setul Formations (Jones, 1978; Metcalfe, 2005). The Setul Formation mostly consists of carbonate rocks and includes two clastic members (Jones, 1978). On the basis of the lithology, the Setul Formation is subdivided into the Lower Setul Limestone, the Lower Detrital Member, the Upper Setul Limestone, and the Upper Detrital Member, in ascending order. The age of these members, which stands on several fossils containing trilobites, graptolites, and conodonts, are Ordovician, Early Silurian, Silurian, and Early Devonian, respectively (Hamada et al., 1975; Jones, 1978). The Thung Song Group is correlated with the Lower Setul Limestone, and the Thong Pha Phum Group is compared with the Lower Detrital Membar, the Upper Setul Limestone, and the Upper Detrital Member (Wongwanich et al., 1990; Metcalfe, 2005).

3.3 Previous works on Early to Middle Paleozoic conodonts in Thailand and Malaysia

Occurrences of Ordovician to Devonian conodonts have been reported by several workers in Thailand and Malaysia. Hagan and Kemper (1976) showed numerous localities of Ordovician to Devonian conodonts in northwestern and western Thailand. Hamada et al. (1975) summarized several biostratigraphic data of conodonts, graptolites, tentaculites, trilobites, corals, brachiopods, gastropods, and cephalopods in Thailand and peninsular Malaysia. Early to Middle Ordovician conodont faunas were reported by Metcalfe (1980) from the Peris area in peninsular Malaysia. Early Ordovician conodont localities and their biostratigraphic ranges were shown by Teraoka et al. (1982), who studied the Tarutao and Thung Song Groups in the Tarutao Island. Description of conodonts and their biostratigraphic studies were undertaken only by Igo and Koike (1967, 1968, 1973) in Langkawi Islands. They described Middle Ordovician to Early Silurian and Late Silurian to Early Devonian conodonts from Langkawi Islands and established four conodont zones based on Middle Ordovician to Early Silurian conodonts. They also mentioned a paleogeographic similarity of these conodont faunas to those of North America and Europe.

4. LITHOLOGY

4.1 Thong Pha Phum area

The studied section in the Thong Pha Phum area is located about 5 km northeast of Thong Pha Phum City, near Khwae Noi River (Figure 2).Ordovician conodonts were found in limestones from the TPP section, which comprises three separated sections, I, II, and III. Section I is located at a roadside cliff along a logging road from Ban Wara Kiang to the Khao Laem Dam. Section II is on hillside, and Section III is along a small plantation road (Figure 3). Based on lithologic characteristics, field observations, and previously known conodont biostratigraphy, rocks of Section I are stratigraphically lower than those of Section II, which are in turn lower than those of Section III. A simplified geologic map of the studied sections and a column showing the lithostratigraphy and sampling levels are shown in Figures 4, 5.

4.1.1 Section I

The rocks strike N 30°W to N 40°W and dip 80° to 85° northeast. Based on the sedimentary structures in limestone and convex upward orientations of bivalve shells, this section is a northeast-upward sequence. The sequence measured in this section is as follows in ascending order; dark gray, massive or partially finely laminated limestone (about 15 m); gray laminated limestone (about 15 m); pale gray massive limestone (about 20 m); and calcareous sandstone (about 10 m). Limestone in the lowest unit consists of pelletal oosparite as seen in thin section. Limestone classification based on microscopic observations follows that of Folk (1959, 1962). Grains are mostly unclear small ooids and peloids along with coarse- to fine-grained quartz and bioclasts. Bioclasts include ostracods, bryozoans, brachiopods, and their fragments. Gray laminated limestone is pelsparite and contains peloids, lumps, and bioclasts coated by some organic matter within sparry calcite cement. This limestone intercalates with thin layers consisting of clasts of bivalve shells, with diameters less than 2 cm. Silt-sized quartz grains are also present. Pale gray massive limestone is an arenaceous biosparite consisting of silt- to dominant fine-grained quartz and bioclasts with sparry calcite cement. Bioclasts contain fragments of crinoids, bryozoans, and trilobites. Peloids and lumps are also present in places. Calcareous sandstone consists mainly of silt-sized to a dominant fine-grained quartz and minor amounts of peloids and bioclasts within sparry calcite and micritic matrix. Bioclasts are less than 1 cm in diameter and include trilobites and bryozoans.

4.1.2 Section II

Section II is located about 300 m northwest of Section I. Rocks strike N 30° to 50°W and dip 70° to 75° northeast. The sequence includes, in ascending order: light gray to gray limestone (about 35 m) and gray massive limestone (about 20 m). The lower gray to light gray limestone is characterized by high-angled cross laminations. This limestone consists of silt-sized quartz grains, ooids and peloids in sparry calcite cement. These grains also form laminations. Bioclasts consisting of bryozoans, crinoids, algae, and other fragments are commonly surrounded by matrix. The upper gray limestone is an arenaceous bioclastic pelsparite consisting of peloids, bioclasts, and silt-sized quartz grains within sparry calcite cement. Bioclasts are of bryozoans, crinoids and algae. The diameter of bioclasts rarely exceeds several centimeters.

4.1.3. Section III

Section III is located about 800 m southeast of section I. Rocks in this section strike N 45° to 55°W and dip 60° to 80° northeast. The complete sequence could not be measured due to soil cover. The sequence measured in this section is as follows in ascending order; fossiliferous gray laminated limestone (about 30 m); red to gray limestone (more than 50 m); gray massive limestone (about 12 m); and black limestone (more than 80 m). The lowest limestone unit is an arenaceous, oolitic, pelletal biosparite consisting of peloids, silt-sized quartz grains, ooids, and bioclasts coated with organic matter within sparry calcite cement. Thin laminations consisting of coarse quartz grains and bioclasts composed of fragments of bivalve shells, algae, and bryozoans are frequently observed in the upper part of this unit. The diameter of bioclasts commonly exceeds 1 cm. The red to gray limestone is a pelsparite consisting of peloids, silt-sized quartz grains, and bioclasts within sparry calcite cement. Bioclasts include fragments of crinoids, ostracods, algae, and bryozoans. The gray massive limestone is a biomicrite composed of bioclasts, the maximum diameter of which frequently exceed 1 cm, and small amounts of silt-sized quartz grains and peloids in a micritic matrix. The highest limestone unit is thickly bedded (30 to 60 cm thick) biomicrite with fragments of sponges, crinoids, ostracods, and cephalopods along with silt-sized quartz grains.

Dark gray to gray, thinly bedded (less than 10 cm thick) sandstone crops out along a logging road. Field observations suggest that this sandstone may be stratigraphically below TPP II.

4.2 Thung Song area

Ordovician conodonts were recovered from the TUS section in the Thung Song area (Figure 6). This section is located at a roadside about 10 km southeast of Thung Song City (8° 00' 420N, 99° 44' 590E) (Figure 7). Locality map of the section and a column showing the lithostratigraphy and sampling levels are shown in Figures 8 and 9. The lithology of this section is characterized by repetitions of bedded limestone with several-mm to 1-cm thick laminations, and thickly bedded limestone, several tens of cm thick. A total thickness of this section is 30 m. These limestones are pale gray and strike N30° E and dip 35° to north. I collected nine samples from the thickly bedded limestone. Under a microscopic observation, this limestone is a lime mudstone with silt-size to very fine-grained quartz within a micritic matrix. Laminations consist of aggregations of quartz grains. Fossils were not observed in thin section samples.

4.3 Thung Wa area

Ordovician conodonts have been recovered from two sections, Section TUW I and TUW II in the Thung Wa area (Figure 6). Locality map of the sections and a column showing the lithostratigraphy and sampling levels are shown in Figures 10-14.

4.3.1 Section TUW 1

This section lies along a road about 10 km northeast of Thung Wa City (7° 10' 808N, 99° 46' 509E) (Figure 10) and is composed of thickly bedded limestones, which are several tens cm thick. Limestones of this section strike N 20° E and dip 15° to south, totally about 20 m thick, are brownish gray in color, and are characterized by a stylolitic texture parallel to the bedding plane. The limestone consists of lime mudstone to fossiliferous micrite, based on microscopic observation (Figure 11). Fine-grained clasts of ostracods, gastropods and bivalves, and silt-sized to very fine-grained quartz are contained in a micritic matrix. The stylolitic texture consists of veins of dolomitized micrite.

4.3.2 Section TUW 2

This section is located about 6 km east of Thung Wa City (Figure 10), and most of its lithological features coincide with those of the TUW 1 section. The limestones are dark gray in color and strike N 30° east and dip 45° to south. The total thickness of this section is about 80 m. The microscopic characteristics of these limestones are similar to those of the TUW 1 section (Figure 13).

4.4 Satun area

The section studied in the Satun area is 30 km north of Satun City (Figures 6). Sampling was done at two sections, ST 1 and ST 2, which are totally about 160 m and 50 m thick, respectively. A simplified geologic map of the studied section and a column showing the lithostratigraphy and sampling levels are shown in Figures 15-19.

4.4.1 Section ST 1

The ST 1 section lies along the Khlong Huai Ba River (Figure 15). Rocks in the sampled section strike N 80° W and dip 45° S. The sequence measured in this section is as follows, in ascending order; gray to red limestone, gray sandstone, and black shale (Figure 16). The lower limestone is subdivided into the gray thin undulatory limestone (about 30 m), gray to yellowish gray nodular limestone (about 55 m), and red nodular limestone (about 45 m), in ascending order. The lowest rock unit consists of thin dark gray layers, whose thickness is normally less than 1 cm, and composed of dark-colored silt and nodular limestone, whose maximum diameter reaches several centimeters. On the basis of a thin-section study, this limestone is classified as biomicrite, composed mainly of bioclasts within micritic matrices. Bioclasts are of ostracods, brachiopods, bryozoa, algae, trilobites, and unidentified shell fragments, of which the maximum diameter is less than 2 mm. Limestone in the upper part of this unit is partly dolomitized, and contains abundant thin shells, less than 1 mm in size. Gray to yellowish gray nodular limestone is characterized by stripes parallel to the bedding plane, which comprise dark gray thin layers and nodular limestone as mentioned above increasing in thickness and width. The thin layers have a three-dimensional structure, and polygonal structures resembling "mud cracks" can be observed on the bedding surface. This limestone is biomicrite and contains ostracods, brachiopods, gastropods, crinoids, trilobites, bivalves, abundant unidentified thin shells, and a minor amount of lumps, less than 4 mm in size, within micritic matrices. Red nodular limestone, which has a similar texture to that in the lower rock unit, is biomicrite consisting of abundant thin shells, ostracods, brachiopods, trilobites, cephalopods, crinoids, and bivalves in micritic matrices. Diameter of bioclasts rarely exceeds more than several centimeters.

The bedding type composed of thin layers and nodular limestone is known from the Thung Song Group in southern peninsular Thailand and the Setul Limestone in the Langkawi Islands of Malaysia (e.g., Teraoka et al., 1982) and is termed "deep water stromatolite" (Wongwanich et al., 1990) or "stylolitic limestone" (Igo and Koike, 1967).

The lower limestone beds are overlain by gray sandstone and black shale. The gray sandstone is more than 2 m in thickness and the black shale is more than 14 m thick. The black shale consisting of clay minerals and silt-sized quartz grains, intercalates several graptolite beds in the lower 4 m. I do not recognize any fossils except graptolites and small sponge fragments. The upper part of the black shale is siliceous and intercalates thin films of less than 1 mm thick consisting of clay minerals.

Wongwanich et al. (1990) distinguished the limestone and fine-grained clastic sequence, which exposed in this area, into the Ordovician Pa Kae Formation and the Ordovician to Silurian Wang Tong Formation. On the basis of the lithologic characters, the lower limestone of the ST 1 section is correlated with the Pa Kae Formation and the gray sandstone and black shale of the section ST 1 are a part of the Wang Tong Formation. Although Wongwanich et al. (1990) distinguished the lower, middle, and upper members in the Wang Tong Formation, the gray sandstone and black shale beds of the present study partly correspond to the middle and upper members. The relationship of the lower limestone and gray sandstone of the ST 1 section is not recognized by my investigation. However, the lower member of Wongwanich et al. (1990), 14 m in thickness, conformably overlies the Pa Kae Formation.

4.4.2 Section ST 2

The ST 2 section is located along Route 4078 (Figure 15). Rocks strike N50°W and dip 80° south. The sequence is subdivided into the lower gray bedded limestone (about 45 m) and the upper black shale (about 5 m) (Figure 18). Under a microscopic observation, the lower limestone is biomicrite consisting of bioslasts and a micritic matrix. Ostracods are dominant and unidentified shell fragments are minor components of bioclasts. The upper black shale seems to be composed mainly of quartz grains less than a silt size, clay minerals, and black organic matter. Many small, triangular shells of tentaculite are also contained.

4.5 Tarutao Island

The Tarutao Island, which ranges 12 km north to south and 5 km east to west, lies about 25 km west of Satun (Figure 6). Bedrock of this island comprises clastic rocks of the Cambrian Tarutao Group and limestones of the Ordovician Thung Song Group. The Thung Song Group exposes in the northeast to southeast part of the island. Ordovician conodonts were found from limestones in the TAR 1 and TAR 2 sections. A map of the Tarutao Island and columns of the studied sections showing the lithostratigraphy and sampling levels are shown in Figures 20-24.

4.5.1 Section TAR 1

Rocks of this section expose along a path to a hilltop, which is located at northwest of the Tarutao Island, and is made up of 40-m thick limestone beds, which strike N 40° W to N 70° W and dip 30° to northeast (Figure 20). The limestone sequence comprises gray massive limestone interbedded with brownish gray, thinly bedded limestones. An interval of massive limestone is more than 50 cm thick. The bedded limestone often shows a cross lamination. This section intercalates a fossiliferous bed about 4 m below the top. The rock samples were collected from massive limestones. Limestone in the lower to middle part of the section is mostly classified into pelsparite by a microscopic observation (Figure 21). Grains consists of abundant peloids and small amount of lump, silt-sized quartz grains, and trilobite fragments. Limestone in the upper part of the section is an oosparite consisting of ooids, lump, and small amount of peloids and silt-sized quartz within sparry calcite cement. Fragments of trilobites and shells are also present in places. The fossiliferous bed is biomicrite with abundant fossils such as cephalopods and trilobites, peloids, and silt-sized quartz grains in micritic matrix.

4.5.2 Section TAR 2

This section lies along a southeastern coast of the island and mainly comprises limestones partly intercalated with shale beds. The rocks strike N 10° W to N 10° E and dip 30° east (Figure 20). The sequence measured in this section is about 1000 m thick, and is as follows in ascending order; argillaceous limestone (about 30 m); gray bedded limestone (about 570 m); red and gray shale interbedded with limestone (about 200 m); gray bedded limestone (about 200 m) (Figure 23). Limestone in the lowest unit consists of dark gray argillaceous limestone, which is bedded with 1- to 30-cm thickness, and comprises silt-sized quartz and calcite grains. Gray limestone overlying the argillaceous limestone is bedded with thickness ranging from 50 cm to 1 m and partly alternated with laminated limestones. These limestones are micrite or pelmicrite consisting of peloids, silt-sized quartz grains and bioclasts in micritic matrix. Bioclasts contain fragments of trilobites and shells. Stylolite textures are observed. The uppermost part of this gray bedded limestone sequence is pelsparite consisting of peloids, lump, and small amount of silt- sized quartz grains within sparry calcite cement. Interbeds of red to gray shale and gray limestone overlie the gray limestone sequence. The shale, mostly red in color, consists of silt-sized quatz and calcite grains and partly contains fine sand-sized grains. Any fossils do not observed in a thin section. The limestone beds, 10 cm to 1 m thick, are micrite or biomicrite under a microscope and include abundant quartz grains. Fragments of trilobites, ostracods, and unidentified shells are also contained. These grains frequently form cross lamination. The shale beds are predominant in the lower 40 m and upper 100 m intervals of the interbed sequence, and the limestone beds are thicker than the shale in the middle 60 m interval. Gray bedded limestone of the uppermost part of the TAR 2 section is micrite or pelmicrite consisting of peloids, silt-sized quartz grains, and fragments of trilobites in micritic matrix.

4.6 Langkawi Islands

Langkawi Islands lies 7 km south of the Tarutao Island. The biggest Langkawi Island ranges 23 km north to south and 30 km east to west. Two studied sections, the LAN 1 and LAN 2 sections, are located in the Langoon Island, northeastern the Langkawi Island (Figures 6, 25). A map of the Langoon Island and a route map of the LAN 1 section are shown in Figure 25. Columns of the studied sections showing the lithostratigraphy and sampling levels are shown in Figures 26-29.

4.6.1 Section LAN 1

The LAN 1 section is located along a western to northwestern coast of the island and consists of limestone and clastic rocks. Rocks in this section strike N 50° W to N 70° W and dip 25° to 40° north. Several faults are present in a middle part of this section, and reconstructed sequences are totally 350 m thick (Figure 26). The LAN 1 section comprises bedded and nodular limestones (about 150 m), black shale (about 20 m), bedded limestone (about 150 m), and shale (about 40 m), in ascending order. These rocks correspond to the Lower Setul Limestone, Lower Detrital Member, Upper Setul Limestone, and Upper Detrital Member, respectively (Igo and Koike, 1967; Jones, 1978).

The lower bedded and nodular limestones comprises the lower, middle, and upper parts. The lower part, about 30 m in thickness, is gray limestone strata, which are bedded with 10-cm to 1-m thickness. Under a microscopic observation, this limestone is pelbiomicrite or biomicrite consisting of peloids, bioclast containing trilobites, ostracods, and unidentified shells, and silt-sized quartz grains in micritic matrix. The middle part of the lower limestone is about 50 m thick and represented as an interbed sequence between laminated limestone and massive limestone, whose interval is 10 cm to 1 m in thickness. In the middle part of this interbed sequence, a set consisting of cross-laminated limestone, limestone with slumping structure, and massive limestone is repeated several times at about 1.5 m intervals. These limestones consist of bioclasts and silt-sized quartz grains in micritic matrix. Bioclasts comprises ostracods and unidentified shells. Gray to red nodular limestone, 70 m in thickness, constitutes the upper part of the lower limestone. The lithology both of outcrops and thin sections of this limestone is quite similar to that of the ST 1 section in the Satun area. The upper 5 m interval of the nodular limestone changes to a bedded limestone. This bedded limestone is biomicrite with a smaller diversity of bioclasts, which are mostly ostracods, than that of the underlying nodular limestone.

Black shale, which is correlated with the Lower Detrital Member (Jones, 1978), consists of clay minerals and silt-sized quartz grains. Graptolites and radiolarians occurs in this shale.

Bedded limestone overlying the black shale is bedded with thickness ranging from 20 to 50 cm throughout the sequence. This limestone is biomicrite consisting of bioclasts and micritic matrix. Bioclasts are predominantly ostracods, and contain small amount of trilobites and shells. Lithology of this limestone resembles that of the uppermost part of the nodular limestone in the LAN 1 section and that of the limestones of the ST 2 section. This bedded limestone sequence in the LAN 1 section is intercalated with several black shale beds, which is 10 to 20 cm in thickness, near the top.

The upper most strata of the LAN 1 section comprises black, gray, pink gray, and greenish gray shales. Althogh the thickness is unidentified, it may reach more than 20 m.

4.6.2 Section LAN 2

Rocks of this section exposed along a southern to southeastern coast of the Langoon Island (Figure 25). This section is 530 m in thickness and consists of gray limestone, which strikes N 40° W to N 60° W and dips 30° N. These limestones are bedded with 10-cm to 1-m thickness throughout the sequence and classified into biomicrite and pelsparite by a microscopic observation. Grains are fragments of ostracods, trilobites, and unidentified shells, peloids, and small amount of quartz grains, which are filled with micritic matrices and partly cemented with sparry calcite. Although the northeast part of the section is above the southwest part in appearance, the conodont biostratigraphy suggests an upward sequence from the northeast side to the southeast side of the section.

5. CONODONT BIOSTRATIGRAPHY

Most of the samples collected in each section yielded conodonts. Ninety five species belonging to 50 genera and 22 unidentified species have been systematically studied (Tables 1-10). Based on the occurrence of stratigraphically important species, totally 31 conodont zones are established in the studied areas. On Tarutao Island, following 7 zones are built up; the Lower Ordovician *Monocostodus sevierensis* range zone and the *M. sevierensis* - *Variabiloconus bassleri* interval zone, in ascending order, in the TAR 1 section (Figure 22); the Lower Ordovician *Rossodus manitouensis* range zone, the *R. manitouensis* - *Teriodon nakamurai* interval zone, the *T. nakamurai* - *V. bassleri* interval zone, Gen. et sp. Indet. 7 range zone, and Gen. et sp. Indet. 7 - *Colaptoconus floweri* interval zone, in ascending order, in the TAR 2 section (Figure 24). In the Thong Pha Phum area, the Lower to Middle Ordovician 4 zones are established in the TPP section; the *Panderodus nogamii* - *Triangulodus brevibasis* interval zone, the *T. brevibasis* range zone, the *T. brevibasis* - *Drepanoistodus costatus* interval zone, and the *Plectodina onychodonta* assemblage zone, in ascending order (Figure 5). In the Thung Wa area, following 2 zones, the Lower to Middle Ordovician *Periodon aculeatus* range zone and the Middle Ordovician *Protopanderodus gradatus* range zone, are made up in the TUW 2 and TUW 1 sections, respectively (Figures 12, 14). In the Thung Song area, the Middle to Upper Ordovician *Panderodus nogamii* range zone is established in the TUS section (Figure 9). The Middle Ordovician to Lower Silurian 5 zones are built up in the Satun area, which are as follows; the *Pygodus anserinus* range zone, the *Baltoniodus* sp. cf. *B. variabilis* range zone, the *Scabbardella altipes* - *Hamarodus europaeus* interval zone, and the *Hamarodus europaeus* range zone, in ascending order, in the ST 1 section (Figure 17); the *Ozarkodina excavata excavata* range zone in the ST 2 section (Figure 19). In the Langkawi Islands, the Lower Ordovician to Lower Devonian 12 zones are set up; the Gen. et sp. Indet. 13 range zone, the *D. costatus* range zone, the *D. costatus* - *Panderodus nogamii* interval zone, the *B.* sp. cf. *B. variabilis* range zone, the Gen. et sp. Indet. 12 range zone, the *H. europaeus* range zone, the *Ozarkodina pennatus proceus* range zone, the *Dapsilodus obliquicostatus* range zone, the *Ozarkodina remscheidensis remscheidensis* range zone, and the *O. r. remscheidensis* - *Pseudooneotodus beckmanni* interval zone, in ascending order, in the LAN 1 section, and the *Scolopodus quadratus* range zone and the *Cooperignathus aranda* range zone, in ascending order, in the LAN 2 section.

5.1 Tarutao Island

5.1.1 Section TAR 1

***Monocostodus sevierensis* range Zone**

This is the lower zone of the TAR 1 section on Taruao Island and has about 24-m thickness (Figure 22). The lower and upper limits of this zone are marked by the first and last occurrences of *Monocostatus sevierensis* (Miller, 1969). This zone also contains *Scolopodus transistans* Druce and Jones, 1971, *Colaptoconus quadraplicatus* (Branson and Mehl, 1933), *Variabiloconus bassleri* (Furnish, 1938), *Teridontus nakamurai* (Nogami, 1967), and *Acodus sevierensis* Miller, 1969. *M. sevierensis* is described from the upper Tremadocian strata in the numerous areas of North America (Miller, 1969, 1980; Landing et al., 2003) and Australia (Druce and Jones, 1971). This species also has been reported from the lower to middle Tremadocian in Canadian Arctic Islands (Nowlan, 1985). *C. quadraplicatus* has been known from the upper Tremadocian strata in the North American Midcontinent areas containing Missouri, Minnesota, Iowa, Texas, and New Mexico (Branson and Mehl, 1933; Furnish, 1938; Ethington and Clark, 1971, 1982; Kennedy, 1980; Repetski, 1982) and the upper Tremadocian sequences of the St. George and Cow Head Groups in Newfoundland (Stouge and Bagnoli, 1988; Ji and Barnes, 1994). Seo et al. (1994) reported this species from the middle Tremadocian to lower Arenigian rocks in the Baegunsan Syncline, Korea. Druce and Jones (1971) firstly described a middle Tremadocian species, *S. transistans*, from Queensland, Australia, and Jones (1971) also reported this species from the Bonaparte Basin, Australia. These lines of biostratigraphic evidence imply an age for the *Monocostodus sevierensis* zone of middle Tremadocian.

***Monocostodus sevierensis - Variabiloconus bassleri* interval Zone**

This is the upper zone of the TAR 1 section and about 16 m in thickness (Figure 22). The base and top of this zone are defined by the last occurrences of *Monocostatus sevierensis* and *Variabiloconus bassleri*, respectively. The conodont fauna occurred from this zone consists of *Teridontus nakamurai*, *Acodus sevierensis*, and two species mentioned above. The lower to middle Tremadocian sequences distributed in North America, including Missouri, Minnesota, Iowa, Texas, New Mexico, New York, Newfoundland, Quebec, and Canadian Arctic Islands, yield *V. bassleri* and *T. nakamurai* (Furnish, 1938; Nowlan, 1985; Landing et al., 1986, 2003; Fåhræus and Roy, 1993; Ji and Barnes, 1994). To sum up, this zone may indicate middle Tremadocian.

5.1.2 Section TAR 2

***Rossodus manitouensis* range Zone**

This zone, about 90 m thick, is the lowermost interval of the TAR 2 section on Taruao Island (Figure 24). The lower and upper boundaries of this range zone are marked by the first and last occurrences of *Rossodus manitouensis* Repetski and Ethington, 1983. Rocks of this zone yield following conodont species; *Teriodon nakanurai*, *Variabiloconus bassleri*, *Colaptoconus bolites* (Repetski, 1982), *Colaptoconus floweri* (Repetski, 1982), *Acanthodus lineatus* (Furnish, 1938), and Gen. et sp. Indet. 19. *R. manitouensis* occurs from the North American Midcontinent areas (Repetski and Ethington, 1983; Nowlan, 1985; Landing et al., 1986) and Newfoundland (Ji and Barnes, 1994), and is an index species of middle to late Tremadocian. *C. bolites* and *C. floweri* were firstly described by Repetski (1982) from the middle to upper Tremadocian sequences in Texas and New Mexico. These species are also known from middle Tremadocian to lower Arenigian rocks in Newfoundland (Ji and Barnes, 1994). *A. lineatus* has been reported from the lower to middle Tremadocian rocks distributed in the North American Midcontinent areas, including Utah, Minnesota, Missouri, and Iowa (Furnish, 1938; Ethington and Clark, 1971, 1982) and the east of Canada (Landing et al., 1986; Fåhræus and Roy, 1993; Ji and Barnes, 1994). These lines of biostratigraphic evidence imply an age for the *Rossodus manitouensis* zone of middle Tremadocian.

***Rossodus manitouensis - Teridontus nakamurai* interval Zone**

The next younger zone of the TAR 2 section ranges from the top of the *Rossodus manitouensis* zone to a horizon about 610 m above the base of the TAR 2 section (Figure 24). The base of this interval zone is defined by the disappearance of *Rossodus manitouensis*, and the top of this zone is taken at the upper limit of the local range of *Teridontus nakamurai*. *T. nakamurai*, *Variabiloconus bassleri*, *Colaptoconus bolites*, *Drepanoistodus concavus* (Branson and Mehl, 1933), and *Acodus sevierensis* range throughout this zone. Gen. et sp. Indet. 1 and Gen. et sp. Indet. 11 have moderately short ranges and occur from the lower to middle part of this zone. The uppermost part of this zone yields *Drepanodus arcuatus* Pander, 1856, *Colaptoconus quadraplicatus* (Branson and Mehl, 1933), *Parapanderodus striatus* (Graves nad Ellison, 1941), and Gen. et sp. Indet. 9. *P. striatus* is a early to middle Arenigian species, which has been known from Utah (Ethington and Clark, 1982), Quebec (Barnes and Poplawski, 1973), and Newfondland (Ji and Barnes, 1994). Therefore, this zone may indicate a middle Tremadocian to early Arenigian.

***Teridontus nakamurai - Variabiloconus bassleri* interval Zone**

This zone covers an interval with 80-m thickness, which is above the *Rossodus manitouensis - Teridontus nakamurai* zone (Figure 24). The base and top of this interval zone is marked by the disappearance of *T. nakamurai* and the last occurrences of *Variabiloconus bassleri*, respectively. This zone is characterized by co-occurrence of *V. bassleri*, *Colaptoconus bolites*, *Drepanoistodus concavus*, *Acodus sevierensis*, *Drepanodus arcuatus*, *Scandodus* sp. cf. *S. furnishi* Lindström, 1955, and *Drepanoistodus forceps* (Lindström, 1955). Gen. et sp. Indet. 9 also occurs from this zone. Seo et al. (1994) reported *S.* sp. cf. *S. furnishi* from the middle Tremadocian to lower Arenigian rocks in the Baeguansan Syncline, Korea. To sum up, this zone is interpreted early Arenigian.

Gen. et sp. Indet. 7 range Zone

The zone is established in an interval above the *Teridontus nakamurai - Variabiloconus bassleri* zone and about 120 m in thickness (Figure 24). This range zone coincides with the stratigraphic range of Gen. et sp. Indet. 7. The other characteristic species of this zone are *Colaptoconus bolites*, *Colaptoconus floweri*, *Acodus sevierensis*, *Acodus comptus* (Branson and Mehl, 1933), *Drepanodus arcuatus*, *Drepanoistodus forceps*, *Conrnuodus longibasis* Lindström, 1955, *Protoprioniodus yapu* Cooper, 1981, and Gen. et sp. Indet. 3. *A. comptus*, which was firstly described by Branson and Mehl (1933) from the Ordovician strata in Missouri, has been reported from Texas, New Mexico, Australia, and Korea. This species indicates late Tremadocian to middle Arenigian (Lee, 1970; Repetski, 1982). *Protoprioniodus yapu* is known to have a stratigraphic range from middle to late Arenigian in Australia, Argentina, and Newfoundland (Cooper, 1981; Albanesi et al., 1998; Johnston and Barnes, 2000; Zhen et al., 2003c). To sum up, this zone may indicate a middle to late Arenigian age.

Gen. et sp. Indet. 7 - *Colaptoconus floweri* interval Zone

This is the uppermost zone of the TAR 2 section and covers an interval ranging from the top of the Gen. et sp. Indet. 7 zone to a horizon about 20 m below the top of the TAR 2 section (Figure 24). The lower boundary of this interval zone is marked by the disappearanceof Gen. et sp. Indet. 7. The upper boundary of this zone is taken at the upper limit of the local range of *Colaptoconus floweri*. Rocks of this zone yield *C. floweri*, *Scolopodus* sp. A, *Filodontus* sp. cf. *F. filosus* Pyle, Barnes, and Ji, 2003, *Drepanoistodus forceps*, Gen. et sp. Indet. 2, Gen. et sp. Indet. 17, and Gen. et sp. Indet. 18. *Filodontus filosus* has been reported from the lower to middle Arenigian rocks in Texas, Utah, New Mexico, and

Newfoundland (Ethington and Clark, 1982; Repetski, 1982; Stouge and Bagnoli, 1988) and from the upper Tremadocian to lower Arenigian rocks in Alberta (Pyle et al., 2003). These lines of biostratigraphic evidence of this zone and the age of the underlying zone indicate an age for the Gen. et sp. Indet. 7 - *Colaptoconus floweri* zone of middle to late Arenigian.

5.2 Thong Pha Phum area

5.2.1 Section TPP

***Panderodus nogamii - Triangulodus brevibasis* interval Zone**

This zone corresponds to the lowermost interval of the TPP section in the Thong Pha Phum area and is about 40-m thickness (Figure 5). The base and top of this interval zone coincide with the first appearances of *Panderodus nogamii* (Lee, 1975a) and *Triangulodus brevibasis* (Sergeeva, 1963), respectively. This zone yields *P. nogamii* and *Juanognathus variabilis* Serpagli, 1974. *P. nogamii* has been reported from several areas of Gondwana, including Korea, Malaysia, Australia, and Argentina (Cantrill and Burrett, 2003), and indicates an age of Darriwilian to early Caradocian (e.g., Lee, 1975a; Watson, 1988). Albanesi (1998a) and Albanesi et al. (1998) showed that *P. nogamii* ranges from late Arenigian to early Darriwilian in Argentina. *J. variabilis* was firstly described from the middle Arenigian strata in Argentina (Serpagli, 1974). This species has been known from the Arenigian to lower Darriwilian sequences in North America, including Alberta, Newfoundland, British Columbia, Texas, New Mexico, and Utah (Ethington and Clark, 1982; Repetski, 1982; Stouge and Bagnoli, 1988; Pohler, 1994; Pyle and Barnes, 2003; Pyle et al., 2003), New South Wales in Australia (Zhen et al., 2003b), Argentina (Albanesi, 1998), and Malaysia (Igo and Koike, 1967). These two species have relatively long stratigraphic ranges. However, on the basis of the age of the overlying zone, this zone may indicate early to middle Arenigian.

***Triangulodus brevibasis* range Zone**

This is the next younger zone of the TPP section and about 70 m thick (Figure 5). This range zone coincides with the stratigraphic range of *Triangulodus brevibasis*. *T. brevibasis*, *Panderodus nogamii*, *Triangulodus larapinensis* (Crespin, 1943), *Drepanoistodus costatus* (Abaimova, 1971), *Erraticodon* sp. B, and *Ansella* sp. D occur from this zone. *T. larapinensis* has been known from New South Wales, the

Georgina Basin, and the Amadeus Basin in Australia, and indicates a middle Arenigian age (Cooper, 1981; Satit and Druce, 1993; Zhen et al., 2003c). Therefore, this zone is inferred to be middle Arenigian.

***Triangulodus brevibasis - Drepanoistodus costatus* interval Zone**

This zone overlies the *Acodus* sp. D zone and has about 320 m thick (Figure 5). The base of this interval zone is defined by disappearance of *Triangulodus brevibasis*. The top of this zone is taken at a upper limit of the stratigraphic range of *Drepanoistodus costatus*. *Panderouds nogamii* has its range throughout this zone. The upper part of this zone yields *Aurilobodus leptosomatus* An, 1983 (in An et al., 1983), *Bergstroemognathus* sp. B, and *Histiodella holodentata* Ethington and Clark, 1982. *A. leptosomatus* has been reported from the upper Arenigian to lower Darriwilian strata in North China and Australia (An et al., 1983; Watson, 1988; Stait and Druce, 1993). *H. holodentata* has been described from the North American Midcontinent areas (Ethington and Clark, 1982), North and South China (Wang et al., 1996), and Australia (Watson, 1988), and has a stratigraohic range in lower Darriwilian. Therefore, this zone is interpreted as middle Arenigian to middle Darriwilian.

***Plectodina onychodonta* assemblage Zone**

This is the uppermost zone of the TPP section and corresponds to a 20-m interval above the *Acodus* sp. D - *Drepanoistodus costatus* zone (Figure 5). The base of this assemblage zone is marked by the appearance of *Plectodina onychodonta* An, 1983 (in An et al., 1983). The top is defined by the disappearance of *Panderouds nogamii*. Gen. et sp. Indet. 14, Gen. et sp. Indet. 16, and Gen. et sp. Indet. 18 are also contained in this zone. *Plectodina onychodonta* is reported from the upper Darriwilian to lower Caradocian rocks in North China (Wang et al., 1996). Therefore, this zone is inferred to be late Darriwilian to early Caradocian.

5.3 Thung Wa area

5.3.1 Section TUW 2

***Periodon aculeatus* range zone**

This zone is established in the TUW 2 section of the Thung Wa area. It covers an interval ranging from a horizon, which is about 3 m above of the base of the TUW 2 section, to the top of the section

(Figure 14). The base of this range zone is taken at the lower limit of the stratigraphic range of *Periodon aculeatus* Hadding, 1913. The top of this zone has not been defined. Any conodont zones underlying this zone can not be established. *P. aculeatus* has been reported from the Arenigian, Darriwilian, and Caradocian strata in North America (Sweet and Bergström, 1962; Bradshaw, 1969; Barnes and Poplawski, 1973; Landing, 1976; Johnston and Barnes, 1999, 2000; Pyle and Barnes, 2003), Sweden (Hadding, 1913; Lindström, 1955; Löfgren, 1978), Poland (Dzik, 1976, 1994), Scotland (Armstrong, 1997), Argentina (Albanesi, 1998a), and China (Wang and Luo, 1984; Wang and Bergström, 1999a; Wang and Qi, 2001). *Protopanderodus gradatus* Serpagli, 1974 occurs in almost all samples from the present study section, and has a stratigraphic range from the lower Arenigian to upper Darriwilian in North America, Australia, Argentina, and China (Serpagli, 1974; Landing, 1976; Ethington and Clark, 1982; An et al., 1985; Stouge and Bagnoli, 1988; Albanesi, 1998b; Johnston and Barne, 1999, 2000; Zhen et al., 2003b). The occurrence together with *Cooperignathus aranda* (Cooper, 1981), *C. nyinti* (Cooper, 1981), *Protoprioniodus yapu* and *Protopanderodus leonardii* Serpagli, 1974 characterizes the lower part of this zone. These species are known to have short stratigraphic ranges, middle to late Arenigian, in Australia and Argentina (e.g., Cooper, 1981; Albanesi et al., 1998). The upper part of this zone is also characterized by *Oistodus* sp. A, which is reported from several areas of North America (Sweet and Bergström, 1962; Bergström and Sweet, 1966; Webers, 1966), Britain (Rhodes, 1953), Norway (Hamar, 1964), Sweden (Löfgren, 1978, 2003), Poland (Dzik, 1994), and Estonia (Viira et al. 2001). This species is known from lower Darriwilian to Ashgillian. These lines of biostratigraphic evidence imply an age for the *Periodon aculeatus* zone of middle Arenigian to late Darriwilian.

5.3.2 Section TUW 1

Protopanderodus gradatus range zone

This zone, about 20 m thick, is established in the TUW 1 section of the Thung Wa area (Figure 12) and marked by an occurrence of *Protopanderodus gradatus*. Its upper and lower limits are not defined. *P. gradatus* generally has a stratigraphic range from the lower Arenigian to upper Darriwilian. *Walliserodus costatus* Dzik, 1976 is present in the middle part of this zone. This species was originally described by Dzik (1976) from the *Lenodus variabilis* zone of the Mójcza Limestone in Poland, and it has rather short stratigraphic range. *W. costatus* also has been reported from the middle Arenigian to lower Darriwilian in Sweden (Löfgren, 1978), and from the upper Arenigian to lower Darriwilian in Argentina (Albanesi, 1998a; Albanesi et al., 1998). Based on these biostratigraphic occurrences, the age of the *Protopanderodus gradatus* range zone is inferred to be middle Arenigian to early Darriwillian.

5.4 Thung Song area

5.4.1 Section TUS

***Panderodus nogamii* range zone**

This is a range zone of the TUS section in the Thung Song area and has about 30-m thickness (Figure 9). This zone is marked by the presence of *Panderodus nogamii* (Lee, 1975a), and its upper and lower limits are not yet known. *Erraticodon* sp. and *Scolopodus* sp. B also occur from this zone. *P. nogamii* has been reported from several areas of Gondwana, including Korea, Malaysia, Australia, and Argentina (Cantrill and Burrett, 2003), ranging from Darriwilian to early Caradocian (e.g., Lee, 1975a; Watson, 1988). Albanesi (1998a) and Albanesi et al. (1998) showed that *P. nogamii* ranges from late Arenigian to early Darriwilian in Argentina. I cannot state a precise age for this zone, but tentatively place it in the late Arenigian to early Caradocian.

5.5 Satun area

5.5.1 Section ST 1

***Pygodus anserinus* range Zone**

This zone is established in the lowest part of the ST 1 section in the Satun area and has about 12 m thick (Figure 17). The lower and upper limits of this zone are marked by the first and last occurrence of *Pygodus anserinus* Lamont and Lindström, 1957. This species is described from the upper Darriwilian stage of the Baltoscandic region (e.g., Dzik, 1994; Zhang, 1998), South China (e.g., Wang et al., 1996; Wang and Qi, 2001), and numerous places in eastern North America (e.g., Sweet and Bergström, 1962). In the British Isles, Bergström and Orchard (1985) reported this species from the upper Darriwilian to lowest Caradocian. This zone also contains *Panderodus gracilis* (Branson and Mehl, 1933), which is known from the Upper Ordovician, in England and Wales (e.g., Rhodes, 1953, 1955; Orchard, 1980) and Austria (e.g., Ferretti and Schonlaub, 2001), the Middle Ordovician to near the top of the

Ordovician in Missouri (e.g., Branson and Mehl, 1933) and Alabama (Sweet and Bergström, 1962), and the middle Caradocian to Ashgillian stage of Taklimakan (Wang and Qi, 2001). Therefore, this zone is interpreted as late Darriwilian to early Caradocian.

***Baltoniodus* sp. cf. *B. variabilis* range Zone**

The next younger zone of the ST 1 section corresponds to the 21-m interval above the *Pygodus anserinus* zone (Figure 17). This range is defined by the first and last occurrences of *Baltoniodus* sp. cf. *B. variabilis* (Bergström, 1962). Other characteristic species of this zone are *Besselodus semisymmetricus* (Hamar, 1966), *Drepanodus arcuatus* Pander, 1856, and *Panderodus* sp. A. *Baltoniodus variabilis* has been described from the middle Caradocian in many places of the world (e.g., Bergström, 1971; Dzik, 1994; Leslie, 2000). Although no description was given, Wang et al. (1996) also reported this species from South China. *Besselodus semisymmetricus* is known from the middle Darriwilian and middle Caradocian stages of Baltoscandia (e.g., Dzik, 1983, 1994; Leslie, 2000). To sum up these lines of biostratigraphic evidence, the age of this conodont zone is assumed to be Caradocian.

***Scabbardella altipes* - *Hamarodus europaeus* interval Zone**

This is an interval zone, about 20 m in thickness, above the *Baltoniodus* sp. cf. *B. variabilis* zone (Figure 17). The lower and upper boundaries of this zone are marked by appearances of *Scabbardella altipes* (Henningsmoen, 1948) and *Hamarodus europaeus* (Serpagli, 1967), respectively. This zone also yields *Dapsilodus mutatus* (Branson and Mehl, 1933), *Protopanderouds* sp. A., and *Drepanoistodus arcuatus*. Most of species of this zone have a comparatively long stratigraphic ranges. On the basis of the ages of the underlying and overlying zones, this zone is interpreted as early to middle Caradocian.

***Hamarodus europaeus* range Zone**

This is the uppermost zone of the ST 1 section in the Satun area and covers an interval ranging from the top of the *Scabbardella altipes* - *Hamarodus europaeus* zone to the top of the limestone sequence of the ST 1 section (Figure 17). The base and top of this range zone are defined by the first and last occurrences of *Hamarodus europaeus*. As far as is known, the lowest occurrence of *H. europaeus* is lower Ashgillian in Europe (e.g., Walliser, 1964; Dzik, 1978, 1994; Orchard, 1980; Ferretti and Barnes, 1997; Ferretti and Serpagli, 1999) and lower Upper Ordovician in South China (Wang et al., 1996). This zone is also characterized by *Protopanderodus liripipus* Kennedy, Barnes, and Uyeno, 1979, *Scabbardella altipes*, and *Ansella* sp. B. *P. liripipus* has been reported from the middle Caradocian to Ashgillian of the Baltoscandia regions (e.g., Dzik, 1976, 1994; Leslie, 2000) and New South Wales (Trotter and Webby, 1994; Zhen et al., 1999), and the middle to upper Caradocian of Taklimakan (Wang and Qi, 2001). *S. altipes* has been reported from the Caradocian of England and Wales (e.g., Orchard, 1980) and Malaysia (Igo and Koike, 1967), the upper Darriwilian to upper Caradocian of Poland (e.g., Dzik, 1994) and South China (Wang et al., 1996), the middle to upper Caradocian of Taklimakan (Wang and Qi, 2001), and Upper Ordovician of North American Midcontinent area (Sweet, 2000), Europe including Italy, Bohemia, and Germany (Ferretti and Barnes, 1997; Ferretti, 1998; Ferretti and Serpagli, 1999), and Australia (Trotter and Webby, 1994). To sum up, this zone may indicate late Caradocian.

5.5.2 Section ST 2

***Ozarkodina excavata excavata* range Zone**

This zone, about 45 m thick, is established in a limestone sequence of the ST 2 section in the Satun area (Figure 19). This range zone coincides with the biostratigraphic range of *Ozarkodina excavata excavata* (Branson and Mehl, 1933), but its upper and lower limits are not defined. This zone yields *O. e. excavata*, *Decoriconus fragilis* (Branson and Mehl, 1933), *Pseudooneotodus beckmanni* (Bischoff and Sannemann, 1958), *Panderodus langkawiensis* (Igo and Koike, 1967), and *Oulodus* sp. A. Although most of these species have relatively long stratigraphic ranges, *P. langkawiensis* is known to occur from the lower to upper Llandovery sequences in North America (Barrick, 1977). Therefore, the age of this zone is assumed to be Llandovery.

5.6 Langkawi Islands

5.6.1 Section LAN 1

Gen. et sp. Indet. 13 range Zone

This zone is established in the Lower Setul Limestone of the LAN 1 section in the Langkawi Islands and corresponds to the lowermost 10-m interval of this section (Figure 27). The base and top of this range zone correspond to the stratigraphic range of Gen. et sp. Indet. 13. The conodont fauna yielded from this zone contains Gen. et sp. Indet. 13, *Triangulodus larapintinensis*, *Scolopodus multicostatus*, Barnes and Tuke, 1970, *Scolopodus quadratus* Pander, 1856, and *Panderodus nogamii*. *T. larapintinensis* has been described from the middle Arenigian rocks in Australia, as mentioned above (Cooper, 1981; Stait and Druce, 1993; Zhen et al., 2003c). *S. quadratus* is known from the Arenigian rocks in numerous areas in the world, including North America (Landing et al., 1976; Repetski, 1982), Sweden (Lindström, 1955; Löfgren, 1978; Fåhræus, 1982), Australia (Zhen et al., 2003b, 2003c), and Argentina (Serpagli, 1974; Albanesi, 1998). These lines of biostratigraphic evidence imply an age for the Gen. et sp. Indet. 13 zone of middle Arenigian.

Drepanoistodus costatus range Zone

This is the next younger zone overlying the Gen. et sp. Indet. 13 zone of the LAN 1 section and about 30 m thick (Figure 27). This range zone coincides with an interval, which yields *Drepanoistodus costatus*. Other characteristic species of this zone are *Panderodus nogamii*, *Prioniodus amadeus* Cooper, 1981, and *Ansella jemtlandica* (Löfgren, 1978). *D. costatus* has been known from the lower Arenigian to middle Darriwilian rocks in Australia (Cooper, 1981; Watson, 1988; Stait and Druce, 1993; Zhen et al., 2003c), Argentina (Albanesi, 1998), and China (Wang and Luo, 1984). *Prioniodus amadeus* was described by Cooper (1981) from middle Arenigian in Australia. Therefore, this zone is interpreted as middle Arenigian.

D. costatus - Panderodus nogamii interval Zone

This is an interval zone ranging from the top of the *Drepanoistodus costatus* zone to a horizon, which is about 75 m above the base of the LAN 1 section (Figure 27). The base of this zone is marked by disappearance of *D. costatus*. The top of this zone is defined by the upper limit of the stratigraphic range of *Panderodus nogamii*. This zone contains *Aurilobodus leptosomatus*, *Periodon* sp. A, and *Bergstroemognathus* sp. A. As previously mentioned, *Panderodus nogamii* has a relatively long stratigraphic range, whose upper limit is lower Caradocian, as mentioned above (Cantrill and Burreitt, 2003). *Aurilobodus leptosomatus* has been known from the upper Arenigian to lower Darriwilian strata in North China and Australia, as mentioned above (An et al., 1983; Watson, 1988; Stait and Druce, 1993). To sum up, this zone may indicate late Arenigian to Darriwilian.

Baltoniodus sp. cf. *B. variabilis* range Zone

This range zone is established in an interval between the horizons, which are about 80 m and 95 m above the base of the LAN 1 section, respectively (Figure 27). The first and last occurrences of

Baltoniodus sp. cf. *B. variabilis* define the base and top of this zone, respectively. Other characteristic species of this zone are *Panderodus gracilis*, *Scabbardella altipes*, *Ansella jemtlandica*, and *Dapsilodus mutatus*. *B. variabilis* has been described from the middle Caradocian in many places of the world, as previously noted (e.g., Bergström, 1971; Dzik, 1994; Leslie, 2000). The other species have longer stratigraphic ranges than that of *B. variabilis*. Therefore, the age of this conodont zone is interpreted as middle Caradocian.

Gen. et sp. Indet. 12 range Zone

This zone covers an about 10-m interval, which is above the *Baltoniodus* sp. cf. *B. variabilis* zone (Figure 27). This range zone coincides with the stratigraphic range of Gen. et sp. Indet. 12. Other characteristic species are *Scabbardella altipes*, *Dapsilodus mutatus*, and *Panderouds gracilis*, which are comparatively long stratigraphic ranges. Based on the ages of the overlying and underlying zones of the Gen. et sp. Indet. 12 zone, this zone is assumed to be Caradociana.

***Hamarodus europaeus* range Zone**

This is the uppermost zone of the Lower Setul Limestone of the LAN 1 section. The base and top of this zone are defined by two horizons, which are about 105 m and 140 m above the base of the LAN 1 section, respectively (Figure 27). This range zone is marked by the lower and upper occurrences of *Hamarodus europaeus*. This zone contains a conodont fauna, consisting *Scabbardella altipes*, *Dapsilodus mutatus*, *Protopanderodus liripipus*, *Panderodus gracilis*, and *Cornuodus longibasis*. This fauna is similar to that of the *H. europaeus* zone of the ST 1 section. As mentioned above, *H. europaeus* is known from the Upper Ordovician sequences in Europe (Walliser, 1964; Dzik, 1978, 1994; Orchard, 1980; Ferretti and Barnes, 1997; Ferretti and Serpagli, 1999) and South China (Wang et al., 1996). *P. liripipus* has been also reported from the Upper Ordovician strata in the Baltoscandia regions (Dzik, 1976, 1994; Leslie, 2000), New South Wales (Trotter and Webby, 1994; Zhen et al., 1999), Taklimakan (Wang and Qi, 2001). These lines of biostratigraphic evidence imply an age for the *Hamarodus europaeus* zone of late Caradocian.

***Pterospathodus pennatus proceus* range Zone**

This zone is established in the lowermost interval, about 15 m thick, of the Upper Setul Limestone of the LAN 1 section (Figure 27). The base and top of this range zone are defined by the first and last occurrences of *Pterospathodus pennatus proceus* (Walliser, 1964). Other characteristic species of this zone are *Dapsilodus praecipuus* Barrikk, 1977, *Dapsilodus hamari* (Igo and Koike, 1967), *Panderodus langkawiensis* (Igo and Koike, 1967), *Panderouds* sp. cf. *P. serratus* Rexroad, 1967, *P. unicostatus* (Branson and Mehl, 1933), and *Decoriconus fragilis*. *Pterospathodus pennatus proceus* has been known from the upper Llandovery to lower Wenlock strata in many areas of the world (e.g., Walliser, 1964; Igo and Koike, 1968; Barrick and Klapper, 1976; Uyeno, 1990; Männik, 1998). However, the next zone, *Dapsilodus obliquicostatus* zone, is an upper Llandovery sequence, as mentioned below. Therefore, the age of the *Pterospathodus pennatus proceus* range zone is inferred to be late Llandovery.

***Dapsilodus obliquicostatus* range Zone**

This is the younger zone overlying the *Pterospathodus pennatus proceus* zone in the LAN 1 section and about 30 m in thickness (Figure 27). The base and top of this range zone are taken at the lower and upper limit of the stratigraphic range of *Dapsilodus obliquicostatus* (Branson and Mehl, 1933), respectively. Occurrences of *Dapsilodus praecipuus*, *Dapsilodus hamari*, *Panderodus unicostatus*, and *Panderodus langkawiensis* range from the underlying zone, and they disappear in the *D. obliquicostatus* zone. *Pseudooneotodus* sp. A and *Dapsilodus sparsus* Barrick, 1977 are restricted their stratigraphic range in this zone. Most of species, which occur from this zone, have relatively long stratigraphic ranges, except for *D. praecipuus* and *P. langkawiensis*. *D. praecipuus* was described by Barrick (1977) from the upper Llandovery to lower Wenlock rocks in Oklahoma. *P. langkawiensis* is known from the lower to upper Llandovery strata (= *P. spasrovi* Drygant, 1974? in Barrick, 1977). These lines of biostratigraphic evidence imply an age for the *Dapsilodus obliquicostatus* zone of late Llandovery.

***Ozarkodina remscheidensis remscheidensis* range Zone**

This zone corresponds to an interval, whose base and top are about 70 m and 120 m above of the lower limit of the Upper Setul Limestone in the LAN 1 section, respectively (Figure 27). This range zone coincides with the stratigraphic range of *Ozarkodina remscheidensis remscheidensis* (Ziegler, 1960). This zone is characterized by occurences of *O. r. remscheidensis*, *Panderodus unicostatus*, *Decoriconus fragilis*, *Belodella resima* (Philip, 1965), *Belodella anomalis* Cooper, 1974, *Ozarkodina excavata excavata*, *Pseudooneotodus beckmanni*, and *Oulodus* sp. A. *O. r. remscheidensis* has been known from the Pridoli to Lochkovian, widely distributed in the world (e.g., Barrick and Klapper, 1992; Corradini et al., 2001; Farrell, 2003). *B. anomalis* has been reported from the upper Ludlow to Pridoli. The other speceis have longer stratigraphic ranges than *O. r. remscheidensis*. However, the ages of the overlying and underlying zones suggest that the *Ozarkodina remscheidensis remscheidensis* zone is

Pridoli.

***Ozarkodina remscheidensis remscheidensis - Pseudooneotodus beckmanni* interval Zone**

This is the uppermost zone of the Upper Setul Limestone in the LAN 1 section and about 15 m thick (Figure 27). The base of this interval zone is defined by disappearance of *Ozarkodina remscheidensis remscheidensis*. The top of this zone is taken at the upper limit of the stratigraphic range of *Pseudooneotodus beckmanni*. Characteristic species of the lower part of this zone are *Ozarkodina remscheidensis eosteinhornensis* (Walliser, 1964), and *Panderinellica* sp. A. The upper part of this zone is characterized by occurrences of *Flajsella stygia* (Flajs, 1967), *Flajsella sigmostygia* Valenzuela-Ríos and Murphy, 1997, *Flajsella* sp. A, *Flajsella* sp. B, and Gen. et sp. Indet. 22 are also containted in this zone. *O. r. eosteinhornensis* is known to be widely distributed in the world and is an indicator of the *O. r. eosteinhornensis* zone, which is one of the global standard zones in the Ludlow to Pridoli. Species of the genus *Panderinellica* firstly appeared in Late Silurian and has existed during a Lochkovian to Emsian age (Farrell, 2003). *F. stygia* and *F. sigmostygia* have been reported from North America, Carnic Alps, and Spain (Flajs, 1967; Valenzuela-Ríos and Murphy, 1997; Valenzuela-Ríos and García, 1998) and indicate a middle Lochkovian age. To sum up the above faunal evidence, this zone interpreted as Pridoli to Lochkovian.

5.6.2 Section LAN 2

***Cooperignathus aranda* range Zone**

This is the lower zone of the LAN 2 section on the Langkawi Islands and established in an lowermost interval, about 150 m thick (Figure 29). The base and top of this zone are taken at the lower and upper limit of the stratigraphic range of *Cooperignathus aranda*. *C. aranda* is known to be restricted its occurrence within a middle to late Arenigian age in North America, Australia, and Argentina (e.g., Cooper, 1981; Ethington and Clark, 1982; Fåhræus and Roy, 1993; Alabnesi et al., 1998; Zhen et al., 2003c), as mentioned above. This zone is characterized by this species, and *Drepanoistodus costatus*, *Scolopodus multicostatus*, and *Jumodontus gananda* Cooper, 1981 area also contained in this zone. *J. gananda* has been reported from the Arenigian rocks in the North American Midcontinent areas, including Utah, Texas, and New Mexico (Ethington and Clark, 1982; Repetski, 1982), New York (Landing, 1976), Newfoundland (Johnston and Barnes, 1999, 2000), Australia (Cooper, 1981; Nicoll. 1992; Zhen et al., 2003c), and Argentina (Serpagli, 1974). *D. costatus* indicates a early Arenigian to middle Darriwilian age (Cooper, 1981; Watson, 1988; Stait and Druce, 1993; Albanesi, 1998; Zhen et al., 2003c), as mentined above. Therefore, the age of this zone is interpreted as middle to late Arenigian.

***Scolopodus quadratus* range Zone**

This is the upper zone of the LAN 2 section. The lower and upper limits of this zone are about 150 m and 270 m above the base of the LAN 2 section, respectively (Figure 29). This zone coincides with a stratigraphic range of *Scolopodus quadratus*. Characteristic species of this zone are *Triangulodus larapintinensis*, *Panderodus nogamii*, *Aurilobodus* sp. cf. *A. leptosomatus*, and *Acodus* sp. A. As mentioned above, *S. quadratus* has been reported from the Arenigian rocks in the world (Löfgren, 1978; Repetski, 1982; Albanesi, 1998; Zhen et al., 2003b, 2003c), and *T. larapintinensis* has been known from the middle Arenigian rocks in Australia (Cooper, 1981; Stait and Druce, 1993; Zhen et al., 2003c). *Aurilobodus leptosomatus* indicates a late Arenigian to early Darriwilian age (Watson, 1988; Stait and Druce, 1993), as previously noted. These lines of biostratigraphic evidence imply an age for the *Scolopodus quadratus* zone of late Arenigian. Any conodont zones overlying this zone can not be established.

6. CORRELATION

6.1 Correlation within the studied sections

I have attempted to correlate the conodont faunas from the studied sections with those from other areas in the world. Correlation of Ordovician to Devonian conodont zones is shown in Figures 30 to 32. Firstly regional correlation within the studied areas is discussed below.

6.1.1 Lower to Middle Ordovician zones

The TAR 1 and TA 2 sections are the Lower Ordovician strata. *Monocostatus sevierensis* and *Variabiloconus bassleri* are indicators of the *M. sevierensis* and *M. sevierensis* - *V. bassleri* zones of the TAR 1 section. Although *M. sevierensis* does not occur from the TAR 2 section, *V. bassleri* is yielded from the *Rosodus manitouensis* zone to the *Teridontus nakamurai* - *V. bassleri* zone of the TAR 2 section. Most of species from the TAR 1 section, such as *V. bassleri*, *T. nakamurai*, *Drepanoistodus concavus*, *Drepanodus arcuatus*, and *Colaptoconus quadraplicatus*, co-occur from the upper 30-m interval of the *R. manitouensis* - *T. nakamurai* zone of the TAR 2 section. The TAR 1 section is compared with strata below the *T. nakamurai* -*V. bariabilis* zone of the TAR 2 section, because the stratigraphic ranges both of *T. nakamurai* and *V. bassleri* attain the top of the TAR 1 section. Therefore, the *M. sevierensis* and *M. sevierensis* - *V. bassleri* zones of the TAR 1 section are correlated with the uppermost part of the *R. manitouensis* - *T. nakamurai* zone of the TAR 2 section (Figures 30 and 31).

The uppermost zone of the TAR 2 section is the upper Lower Ordovician contemporaneous with the lowermost part of the TPP, TUW 2 and LAN 2 sections. However, species of the TAR 2 section are not common in the other sections.

The TPP, TUS, TUW 1, TUW 2, and LAN 2 sections and the lower part of the LAN 1 section contain the uppermost Lower Ordovician or Middle Ordovician. The TUW 1 section does not yield species, which occurs from the other sections. Although the TUS section shares *Panderodus nogamii* with the TPP, LAN 1, and LAN 2 sections, this species has a relatively long stratigraphic ranges and is unuseful for a detailed correlation. Therefore, correlations of the TPP, TUW 2, and LAN 2 sections and the lower part of the LAN 1 section are discussed here.

The lowermost and uppermost zones of the TPP section, the *P. nogamii* - *Acodus* sp. D zone and the

Plectodina onychodonta zone, yield *P. nogamii*, which also occurs from other sections. The *Acodus* sp. D zone of the TPP section shares *Triangulodus larapintinensis* with the *Protopanderodus gradatus* zone of the TUW 2 section, the Gen. et sp. Indet. 13 zone to the lower part of the *Drepanoistodus costatus* zone of the LAN 1 section, and the *Scolopodus quadratus* - *Cooperignathus aranda* zone of the LAN 2 section. *D. costatus*, which defines the upper boundary of the *Acodus* sp. D - *D. costatus* zone of the TPP section, is also the nominal species of the *D. costatus* zone of the LAN 1 section. *Aurilobodus leptosomatus* occurs from the upper part of the *Acodus* sp. D - *D. costatus* zone of the TPP section and the uppermost part of the *D. costatus* - *P. nogamii* zone of the LAN 1 section. *C. aranda* and *S. quadratus* determine the *C. aranda* zone and the *S. quadratus* - *C. aranda* zone of the LAN 2 section, and are common species to the *P. gradatus* zone of the TUW 2 section and the Gen. et sp. 13 zone to the *D. costatus* zone of the LAN 1 section, respectively. To sum up above, the *Acodus* sp. D zone of the TPP section are correlated with the lower to middle part of the *P. gradatus* zone of the TUW 2 section, the Gen. et sp. Indet. 13 zone to the lower part of the *D. costatus* zone of the LAN 1 section, and the *C. aranda* zone to the *S. quadratus* - *C. aranda* zone of the LAN 2 section. The *Acodus* sp. D - *D. costatus* zone of the TPP section is compared with the *D. costatus* zone to the *D. costatus* - *P. nogamii* zone of the LAN 1 section (Figures 30 and 31).

6.1.2 Upper Ordovician zones

The ST 1 and LAN 1 sections are Upper Ordovician and share most of their characteristic species, containing *Baltoniodus* sp. cf. *B. variabilis*, *Scabbardella altipes*, *Cornuodus longibasis*, *Dapsilodus mutatus*, *Hamarodus europaeus*, and *Protopanderodus liripipus*. The *Pygodus anserinus* zone of the ST 1 section is defined by the occurrence of *P. anserinus*, which is not yielded from the LAN 1 section. *Panderodus gracilis* is also contained in the *P. anserinus* zone and has a relatively long stratigraphic range. Therefore, the *P. anserinus* zone of the ST 1 section can not be compared with any zones of the LAN 1 section. The *B.* sp. cf. *B. variabilis* zones both of the ST 1 and LAN 1 sections are correlated with each other, because of the presence of the index species, *B.* sp. cf. *B. variabilis*. The *S. altipes* - *H. europaeus* zone of the ST 1 section yields *S. altipes* and *D. mutatus*, which have the stratigraphic ranges from the *B.* sp. cf. *B. variabilis* zone to the *H. europaeus* zone. The *H. europaeus* zones both of the ST 1 and LAN 1 sections are determined by the occurrence of *H. europaeus* and share *S. altipes*, *D. mutatus*, and *Protopanderodus liripipus*. Therefore, these two *H. europaeus* zones are compared with each other, and the underlying the *S. altipes* - *H. europaeus* zone of the ST 1 section and the Gen. et sp. Indet. 12

zone of the LAN 1 section are also equivalent (Figures 30 and 31).

6.1.3 Silurian to Devonian zones

Conodont zones of the ST 2 section are Silurian and those of the upper part of the LAN 1 section are Silurian to Devonian. Species yielded from the *Ozarkodina excavata excavata* zone of the ST 2 section also occur from the LAN 1 section. *O. e. excavata*, *Pseudooneotodus beckmanni*, and *Panderodus langkawiensis* are restricted to occur in the LAN 1 section. However, the stratigraphic range of *P. langkawensis* do not overlap those of *O. e. excavata* and *P. beckmanni* in the LAN 1 section. *P. beckmanni* has been reported from the Lower Ordovician to Upper Silurian strata in numerous areas of the world (Uyeno, 1990). Occurrence of *O. e. excavata* ranges from the Lower to Upper Silurian sequences (Barrik and Klapper, 1976; Armstrong, 1990; Uyeno, 1990). On the other hand, *P. langkawensis* has been known from the Llandovery rocks (Barrik, 1977). The stratigraphic range of this sepcies is limited to the *Pterospathodus pennatus proceus* zone to the *Dapsilodus obliquicostatus* zone in the LAN 1 section. Therefore, the *O. e. excavata* zone of the ST 1 section is correlated with the *P. p. proceus* zone to the *D. obliquicostatus* zone in the LAN 1 section (Figure 32).

6.2 Comparison with Ordovician conodont biostratigraphy in the world

Ordovician conodont zones in the studied areas are correlated with those from Thailand, Malaysia, Australia, North China, South China, the North Atlantic areas, and the North American Midcontinent areas. Correlation of Ordovician conodont zones is shown in Figures 30 and 31.

6.2.1 Thailand and Malaysia

To date, Ordovician conodont faunas have been reported from Tarutao Island, the Langkawi Islands, and the Peris area in peninsular Malaysia (Igo and Koike, 1967, 1968; Metcalfe, 1980; Teraoka et al., 1982). Although Teraoka et al. (1982) identified 28 species of Tremadocian to Arenigian conodont, their conodont faunas have few species in common with those from the TAR 1 and TAR 2 sections of the present study. This reason is that the studied sections by Teraoka et al. (1982) are totally more than 2,000 m thick and range a much longer time than the TAR 1 and TAR 2 sections. Therefore, it is impossible to compare with these faunas.

Metcalfe (1980) showed a list of Ordovician conodonts from the Setul Limestone in the Peris area, peninsular Malaysia, and stated their ages. He recovered three conodont faunas from the locality 1, 2, and 3 in the Peris area. The age of the faunas from the locality 1 and 3 is Early Ordovician and the fauna from the locality 2 is Middle Ordovician. These faunas do not share any species with faunas of the present study, except for *Panderodus nogamii* (= *Scolopodus* sp. in Metcalfe, 1980) in the fauna from the locality 1. However, this species is unuseful for the correlation due to its long stratigraphic range.

Igo and Koike (1967, 1968) described Middle Ordovician to Early Silurian conodonts from the Langkawi Islands and established four conodont zones as follows; the *Scolopodus staufferi* - *Scolopodus giganteus*, *Scabbardella altipes*, *Acodus mutatus* - *Dapsilodus hamari*, and *Panderodus unicostatus* zones, in ascending order. These zones yield several species in common with the LAN 1 section in this study. Ordovician species such as *Scabbardella altipes*, *Triangulodus larapintinensis*, *Juanognathus variabilis*, and *Panderodus nogamii* are described by Igo and Koike (1967) as *Acodus similaris* Rhodes, 1955 and *Drepanodus altipes* Hennigsmoen, 1948, *Scolopodus vulgaris* (Branson and Mehl, 1933), *Acontiodus* sp. B, and *Scolopodus* sp. cf. *S. bassleri* Furnish, 1938, respectively. Silurian species, *Panderodus unicostatus*, *Panderodus langkawiensis*, and *Dapsilodus hamari*, also have reported by Igo and Koike (1967). Consequently, the Gen. et sp. Indet. 13 zone to the *Hamarodus europaeus* zone in the LAN 1 section in this study is compared with the *Scolopodus staufferi* - *S. giganteus* zone to the lower part of the *Acodus mutatus* - *Dapsilodus hamari* zone of Igo and Koike (1967). The *Pterospathodus pennatus proceus* zone to the *Dapsilodus obliquicostatus* zone of this study is roughly correlated with the upper part of the the *Acodus mutatus* - *Dapsilodus hamari* zone to the *Panderodus unicostatus* zone of Igo and Koike (1967).

6.2.2 Australia

Ordovician conodont faunas are reported from the several basins in Australia. Tremadocian conodont zones in the northeast of Australia are recognized by Druce and Jones (1971) and Jones (1971) as follows; the *Cordylodus proavus*, *Oneotodus bicuspatus* - *Drepanodus simplex*, *Cordylodus oklahomensis* - *C. lindstromi*, *Cordylodus prion* - *Scolopodus*, *Cordylodus rotundatus* - *C. angulatus*, *Chosonoduna herfurthi* - *Acodus*, and *Drepanodus*? *gracilis* - *Scolopodus sexplicatus* zones, in ascending order (Figure 30). Lower to Middle Ordovician strata, such as the Horn Valley Siltstone in the Amadeus Basin, the Coolibah Formation in the Georgina Basin, the Tabita Formation in the Koonenberry Belt, and the Hensleigh Siltstone in the Wahringa area, yield conodont faunas (Figure

30) (Cooper, 1981; Stait and Druce, 1993; Zhen et al., 2003b, 2003c). Middle Ordovician faunas have been reported from the Goldwyer and Nita Formations in the Canning Basin (Figure 30) (Watson, 1988). The Wahringa Limestone in the Wahringa area and the Cliefden Caves Limestone and the Malongulli Formation in the Cliefden Caves area yield Late Ordovician faunas (Figure 30) (Trotter and Webby, 1994; Zhen et al., 1999; Zhen et al., 2003a). These zones and sequences are correlated with the Ordovician zones in this study, except for the TUW 1 and TUS sections, which yield quite a few conodonts.

Section TAR 1

Variabiloconus bassleri, which ranges throughout the TAR 1 section, and *Scolopodus transistans* were reported from the Bonaparte Gulf Basin and the Ninmaroo Formation in the northeast of Australia (Druce and Jones, 1971; Jones, 1971). *V. bassleri* is known from the *Cordylodus prion - Scolopodus toepanodus* to *Drepanodus*? *gracilis - S. sexplicatus* zones in Australia. *S. transitans* occurs from the *Cordylodus rotundatus - C. angulatus* to *D.*? *gracilis - Scolopodus sexplicatus* zones in Australia. Therefore, the *Monocostatus sevierensis* to *M.sevierensis - V. bassleri* zones in the TAR 1 section are approximately compared with the *C. rotundatus - C. angulatus* to *D.*? *gracilis - S. sexplicatus* zones in Australia (Figure 30).

Section TAR 2

The TAR 2 section shares *Rossodus manitouensis* (=*Acodus oneotensis* Furnish, 1938, in Druce and Jones, 1971 and Jones, 1971), which determines the lowermost zone in the TAR 2 section, with the *Chosonoduna herfurthi - Acodus* to *Drepanodus*? *gracilis - Scolopodus sexplicatus* zones in Australia. Therefore, the *R. manitouenesis* zone in the TAR 2 section is equivalent to the *C. herfurthi - Acodus* to *D.*? *gracilis - S. sexplicatus* zones (Figure 30). The middle to upper part of the TAR 2 section does not yield common species to Australia, except for *Protoprioniodus yapu*. This species has been described from the Horn Valley Siltstone and the Tabita Formation (Cooper, 1981; Zhen et al., 2003c). However, these strata are not directly compared with each other, because this species has a stratigraphic ragne from middle to late Arenigian and the other characteristic species of the Australian faunas do not occur from the TAR 2 section.

Section TPP

Five species from the TPP section, *Panderodus nogamii*, *Juanognathus variabilis*, *Triangulodus* *larapintinensis*, *Drepanoistodus costatus*, *Aurilobodus leptosomatus*, and *Histiodella holodentata*, have been also reported from Australia. *P. nogamii*, which occur throughout the TPP section, has been described from the Horn Valley Siltstone, the Tabita Formation, the Hensleigh Siltstone, the Goldwyer Formation, and the Nita Formation (Cooper, 1981; Watson, 1988; Zhen et al., 2003b, 2003c). *J. variabilis* and *T. larapintinensis* occur from the *P. nogamii - Trinangulodus brevibasis* zone and the *T. brevibasis* zone of the TPP section, respectively. *J. variabilis* has been known from the Hensleigh Siltstone (Zhen et al., 2003b). However, occurrence of this species in other areas is known from early Arenigian to early Darriwilian (e.g., Serpagli, 1974; Ethington and Clark, 1982; Pohler, 1994). *T. larapintinensis* has been reported from the Horn Valley Siltstone, the Coolibah Formation, the Tabita Formation, the Goldwyer Formation, and the Nita Formation (Watson, 1988; Stait and Druce, 1993; Cooper, 1981; Zhen et al., 2003c). Therefore, the *P. nogamii - T. brevibasis* zone and the *T. brevibasis* zone of the TPP section can not be compared with any particular sequences in Australia.

The upper limit of the *T. brevibasis - D. costatus* zone is defined by *D. costatus*, which has been known from the Horn Valley Siltstone (= *Drepanoisotdus pitjanti*, in the Cooper, 1981), the Coolibah Formation, the Tabita Formation, and the Goldwyer Formation (Cooper, 1981; Watson, 1988; Stait and Druce, 1993; Zhen et al., 2003c). Watson (1988) described *A. leptosomatus* (=*Juanognathus leptosomatus*, in Watson, 1988) and *H. holodentata*, which characterize the *T. brevibasis - D. costatus* zone of the TPP section, from the Goldwyer Formation (Watson, 1988). To sum up above, the upper part of the *T. brevibasis - D. costatus* zone of the TPP section is contemporaneous with the Goldwyer Formation (Figure 30).

Section TUW 2

This section shares most of species with the Lower to Middle Ordovician strata in Australia. The Horn Valley Siltstone contains *Cooperignathus aranda* (=*Protoprioniodus aranda* Cooper, 1981), *Cooperignathus nyinti* (=*Protoprioniodus nyinti* Cooper, 1981), *Eratticodon patu*, *Protoprioniodus yapu*, and *Trigonodus larapintinensis*, all of which are present in the lower to middle parts of the *Periodon aculeatus* zone in the present study (Cooper, 1981). The Coolibah Formation yields a conodont fauna comparable to that of the TPP section, such as *C. aranda* (=*Protoprioniodus nyinti*, in Stait and Druce, 1993), *Paroistodus originalis*, and *T. larapintinensis* (Stait and Druce, 1993). Zhen, et al. (2003c) reported *C. aranda*, *C. nyinti*, *E. patu*, *Protopanderodus gradatus*, *P. leonardii*, *P. yapu*, and *T. larapintinensis* from the Tabita Formation. Therefore, the lower part of the *Periodon aculeatus* zone of the TUW 2 section is correlative with the Horn Valley Siltstone, the Coolibah Formation, and the

Tabita Formation (Figure 30).

Section LAN 1

The Gen. et sp. Indet. 13 zone, *Drepanoistodus costatus* zone, and *D. costatus - Pandeoruds nogamii* zone of the LAN 1 section yields several sratigraphically impotrant speceis, including *Scolopodus quadratus*, *Prioniodus amadeus*, and *Aurilobodus leptosomatus*. *S. quadratus* is known from the Hensleigh Siltstone and the Tabita Formation (Zhen et al., 2003b, 2003c), and *P. amadeus* was described by Cooper (1981) from the Horn Valley Siltstone. Watson (1988) reported *A. leptosomatus* from the Goldwyer Formation. Althogh *D. costatus*, *P. nogamii*, and *Triangulodus larapintinensis* have comparatively long stratigraphic ranges, these species are common to the LAN 1 section, the Horn Valley Siltstone, the Coolibah Formation, the Tabita Formation, and the Goldwyer Formation (Cooper, 1981; Watson, 1988; Stait and Druce, 1993; Zhen et al., 2003c). The age of the Hensleigh Siltstone is slightly older than those of the other Lower Ordovician sequences in Australia, and predominant species of the Hensleigh Siltstone do not occur from the LAN 1 section. To sum up above, the Gen. et sp. Indet. 13 zone and *Drepanoistodus costatus* zone of the LAN 1 section may be correlated with the Horn Valley Siltstone, the Cooligah Formation, and the Tabita Formation. The *D. costatus - Pandeoruds nogamii* zone of the LAN 1 section is compared with the Goldwyerf Formation.

The *Baltoniodus* sp. cf. *B. variabilis* zone to the *Hamarodus europaeus* zone of the LAN 1 section share *Ptoropanderodus liripipus*, *Scabbardella altipes*, and *Dapsilodus mutatus* with the Upper Ordovician strata in Australia. However, *H. europaeus*, which is the index species of the *H. europaeus* zone, is not known from Australia. *Protopanderodus liripipus* has been reported from and the Malachi's Hill Beds (Zhen et al., 1999). The lower part of the Malongulli Formation yields *P. liripipus*, *Dapsilodus mutatus*, and *Scabbardella altipes* (Trotter and Webby, 1994). On the basis of these species, the *B.* sp. cf. *B. variabilis* zone to the *H. europaeus* zone are partially corelated with the Malachi's Hill Beds and the lower part of the Malongulli Formation (Figure 30).

Section LAN 2

Drepanoistodus costatus, *Panderodus nogamii*, *Triangulodus larapintinensis*, *Scolopodus quadratus*, and *Cooperignathus aranda* are common to the LAN 2 section and the Australian strata, as mentioned above. *Jumodontus ganada* also occur from the LAN 2 section, the Horn Valley Siltstone, and the Tabita Formation (Cooepr, 1981; Zhen et al., 2003c). Therefore, the *C. aranda* and *S. quadratus - C. aranda* zones of the LAN 2 section are approximately correlated with the Horn Valley Siltstone, the

Coolibah Formation, and the Tabita Formation (Figure 30).

Section ST 1

The *Scabbardella altipes* - *Hamarodus europaeus* zone and the *H. europaeus* zone of the ST 1 section share *Ptoropanderodus liripipus*, *S. altipes*, and *Dapsilodus mutatus* with the Malachi's Hill Beds and the lower part of the Malongulli Formation in Australia. The *S. altipes* - *H. europaeus* to *H. europaeus* zones of the ST 1 section is partially equivalent to the previous two sequences in Australia (Figure 30).

6.2.3 North China

According to Wang et al. (1996), 14 Ordovician conodont zones are recognized in North China, as Figure 31. The TAR 1, TAR 2, and TPP sections in the studied areas share several species with North China.

Sections TAR 1 and TAR 2

Teridontus nakamurai and *Monocostatus sevierensis* have relatively long stratigraphic ranges. *Colaptoconus quadraplicatus* (= *Glyptoconus quiadraplicatus*, in Wang et al., 1996) is known from the *Cordylodus quadraplicatus* - *Cordylodus herfurthi* zone to the *Serratognathus bilobatus* zone in North China. On the basis of these species, zones of this study may be correlated as follows; the *M. sevierensis* zone in the TAR 1 section and the *Rossodus manitouensis* zone to the Gen. et al. Indet. 7 zone in the TAR 2 section are roughly compared with the *C. quadraplicatus* - *C. herfurthi* zone to the *S. bilobatus* zone in North China (Figure 31)

Section TPP

Histiodella holodentata and *Plectodina onychodonta*, which occur from the TPP section, are characteristic species of the *Tangshanodus tangshanensis* to *Eoplacognathus suecicus* - *P. onychodonta* zones and the *E. suecicus* - *P. onychodonta* to *Aurilobodus serratus* zones of North China, respectively (Wang et al., 1996). Therefore, the upper part of the *T. brevibasis* - *Drepanoistodus costatus* zone in the TPP section is compared with the *T. tangshanensis* zone to the *E. suecicus* - *P. onychodonta* zone in North China. The *P. onychodonta* zone in the TPP section is equivalent to the *E. suecicus* - *P. onychodonta* zone to *A. serratus* zone in North China (Figure 31).

6.2.4 South China

Following 19 zones of Ordovician conodont were established in South China by Wang et al. (1996); the *Cordylodus proavus*, *Cordylodus intermedius*, *Cordylodus angulatus*, *Cordylodus quadraplicatus*, *Paltodus deltifer*, *Serratognathus*, *Oepikodus evae*, *Baltoniodus trianguralis*, *Baltoniodus navis*, *Paroistodus originalis*, *Lenodus variabilis*, *Eoplacognathus suecicus*, *Pygodus serra*, *Pygodus anserinus*, *Baltoniodus variabilis*, *Baltoniodus alobatus*, *Hamarodus europaeus*, *Protopanderodus insculptus*, and *Amorphognathus ordovicicus* zones, in ascending order (Figure 31). Correlations between these zones and those of the TAR 1, TAR 2, TPP, ST 1, and LAN 1 sections, containing several stratigraphically useful species, are discussed below.

Sections TAR 1 and TAR 2

Teridontus nakamurai, *Monocostatus sevierensis*, and *Colaptoconus quadraplicatus* have been reported from the lower Lower Ordovician, the *Cordylodus proavus* to *Cordylodus quadraplicatus* zones in South China (Wang et al., 1996). However, the other species contained in the TAR 1 and TAR 2 sections have been known to occur from the middle to late Early Ordovician strata. Therefore, the TAR 1 and TAR 2 sections seems to be slightly younger than the zones in South China mentioned above (Figure 31).

Section TPP

Juanognathus variabilis occurs both from the *Panderodus nogamii*- *Acodus* sp. D zone of the TPP section and the *Serratognathus* to *Baltoniodus trianguralis* zones and the *Paroistodus originalis* zone in South China (Wang et al., 1996; Wang and Bergström, 1999a). The upper part of the *Acodus* sp. D - *Drepanoistodus costatus* zone in the TPP section is characterized by *Histiodella holodentata*, which occurs from the *Eoplacognathus suecicus* zone in South China (Wang et al., 1996). The four zones of the TPP section are approximately correlated with the *Baltoniodus trianguralis* zone to the *Eoplacognathus suecicus* zone in South China (Figure 31).

Section LAN 1

The lowermost part of the LAN 1 section does not share any species with South China. However, the *Baltoniodus* sp. cf. *B. variabilis* zone to the *Hamarodus europaeus* zone in the LAN 1 section yield several common species to South China, such as *Scabbardella altipes*, *Dapsilodus mutatus*, *Ptoropanderodus liripipus*, and *H. europaeus* (An et al., 1985; Wang et al., 1996). *S. altipes* and *D. mutatus* are representative species of the *B.* sp. cf. *B. variabilis* zone to the *H. europaeus* zone in the LAN 1 section and have reported from the the *Pygodus serra* zone to the *H. europaeus* zone in South China (An et al., 1985; Wang et al., 1996). *P. liripipus*, which is one of the characteristic species of the *H. europaeus* zone of the LAN 1 section, has been known from the *Baltoniodus variabilis* zone to the *Amorphognathus ordovicicus* zone in South China (An et al., 1985; Wang et al., 1996). Occurrence of *H. europaeus*, the nominate species of the *Hamarodus europaeus* zone of the LAN 1 section, is restricted to the *H. europaeus* zone in South China (An et al., 1985; Wang et al., 1996). *B. variabilis* (= *Prioniodus variabilis* Bergström, 1962, in Wang et al., 1996) occurs from the *B. variabilis* and *Baltoniodus alobatus* zones in South China (Wang et al., 1996). To sum up the above faunal evidence, the *B.* sp. cf. *B. variabilis* zone, the Gen. et sp. 12 zone, and the *H. europaeus* zone in the LAN 1 section are compared with the *B. variabilis*, *B. alobatus*, and *H. europaeus* zones in South China, respectively (Figure 31).

Section ST 1

The *Baltoniodus* sp. cf. *B. variabilis* zone to the *Hamarodus europaeus* zone in the ST section, as well as the LAN 1 section, yield *Scabbardella altipes*, *Dapsilodus mutatus*, *Ptoropanderodus liripipus*, and *H. europaeus*, which also occur from South China (An et al., 1985; Wang et al., 1996). *Pygodus anserinus* defines the *P. anserinus* zone both in the ST 1 section and South China (An et al., 1985; Wang et al., 1996). These lines of biostratigraphic evidence indicate that the *P. anserinus* zone, the *B.* sp. cf. *B. variabilis* zone, *S. altipes* - *H. europaeus* zone, and the *H. europaeus* zone in the ST 1 section are correlated with the *P. anserinus*, *B. variabilis*, *B. alobatus*, and *H. europaeus* zones in South China, respectively (Figure 31).

6.2.5 North Atlantic area

Webby et al. (2004) compiled the conodont sequence in the North Atlantic areas as follows, in ascending order; the *Cordylodus angulatus*, *Paltodus deltifer*, *Paroistodus proteus*, *Prioniodus elegans*, *Oepikodus evae*, *Baltoniodus triangularis*, *Baltoniodus navis*, *Paroistodus originalis*, *Baltoniodus norrlandicus*, *Lenodus variabilis*, *Eoplacognathus suecicus*, *Pygodus serra*, *Pygodus anserinus*, *Amorphognathus tvaerensis*, *Amorphognathus superbus*, and *Amorphognathus ordovicicus* zones (Figure 31). The TUW 1, ST 1, and LAN 1 sections in this study share several important species with the North Atlantic areas.

Section TUW 1

Walliserodus costatus ranges a more restricted sequence than that of *Protopanderodus gradatus* (Dzik, 1976; Löfgren, 1978). The *P. gradatus* zone in the TUW 1 section is correlated with the *Baltoniodus triangularis* to *Lenodus variabilis* zones, which occur *Walliserodus costatus*, in the North Atlantic areas (Figure 31).

Section LAN 1

The Middle Ordovician strata in the LAN 1 section do not contain any common species to the North Atlantic areas. Upper Ordovician strata of the LAN 1 section yield several species, which also occur from the North Atlantic areas. *Scabbardella altipes* and *Dapsilodus mutatus* occur from the *Baltoniodus* sp. cf. *B. variabilis* zone to the *Hamarodus europaeus* zone in the LAN 1 section, and are representative species of the *Pygodus anserinus* to *Amorphognathus ordovicicus* zones in the North Atlantic area (Dzik, 1976, 1994; Orchard, 1980; Ferretti, 1998). *Protopanderodus liripipus*, which is one of the nominal species of the *H. europaeus* zone of the ST 1 section, has been reported from the *Amorphognathus superbus* and *A. ordovicicus* zones in the North Atlantic areas (Orchard, 1980; Dzik, 1994; Leslie, 2000). *H. europaeus*, which is the nominate species of the *H. europaeus* zone of the LAN 1 section, is a representative species of the *A. superbus* and *A. ordovicicus* zones in the North Atlantic areas (Walliser, 1964; Dzik, 1978, 1994; Orchard, 1980). *Baltoniodus variabilis* is a characteristic species of the lower part of the *Amorphognathus tvaerensis* zone (Bergström, 1971; Dzik, 1976, 1994; Leslie, 2000). These lines of biostratigraphic evidence indicate that the *B.* sp. cf. *B. variabilis* zone, the Gen. et sp. 12 zone, and the *H. europaeus* zone in the LAN 1 section are correlative with the lower part of the *A. tvaerensis* zone, the upper part of the *A. tvaerensis*, and the *A. superbus* zone in the North Atlantic area. The upper boundary of the *H. europaeus* zone in the LAN 1 section may not attain Ashgillian, because this zone does not contain the latest Ordovician conodonts, such as *A. ordovicicus* Branson and Mehl, 1933 and *Protopanderodus insculptus* (Branson and Mehl, 1933) (Figure 31).

Section ST 1

Several species in the ST 1 section, as well as in the LAN 1 section, are in common with the North Atlantic areas. *Scabbardella altipes*, *Dapsilodus mutatus*, *Protopanderodus liripipus*, and *Hamarodus europaeus* are representative species of Upper Ordovician in the North Atlantic areas, as noted above.

Occurrence of *Pygodus anserinus* determines the *P. anserinus* zone both in the ST 1 section and the North Atlantic areas (Bergström, 1971; Dzik, 1994; Zhang, 1998). To sum up the above faunal evidence, the *P. anserinus*, *Baltoniodus* sp. cf. *B. variabilis*, *S. altipes - H. europaeus*, and *H. europaeus* zones in the ST 1 section are correlative with the *Pygodus anserinus* zone, the lower part of the *Amorphognathus tvaerensis* zone, the upper part of the *Amorphognathus tvaerensis* zone and the *Amorphognathus superbus* zone in the North Atlantic area, respectively (Figure 31). The upper boundary of the *H. europaeus* zone in the ST 1 section may not attain Ashgillian by the same reason as the LAN 1 section.

6.2.6 North American Midcontinent

According to Ethington and Clark (1982) and Sweet and Tolbert (1997), the standard Ordovician conodont sequence in the North American Midcontinent area can be summarized as follows, in ascending order: the *Cordylodus proavus*, *C. intermedius*, *C. linestromi*, *C. lapetognathus*, *C. angulatus*, *Rossodus manitouensis*, Low Diversity Interval, *Mederodus dianae*, *Diaphorodus deltatus - Oneotodus costatus*, *Oepikodus communis*, *Reutterodus andinus*, *Tripodus laevis*, *Histiodella altifrons*, *H. sinuosa*, *H. holodentata*, *Phragmodus "pre-flexuosus"*, *Cahabagnathus friendsvillensis*, *C. sweeti*, *Periodon aculeatus*, *Erismodus quadridactylus*, *Belodina compressa*, *Phragmodus undatus*, *Plectodina tenuis*, *Belodina confluens*, *Oulodus velicuspis*, *Oulodus robustus*, *Aphelognathus grandis*, *Aphelognathus divergens*, and *Aphelognathus shetzeri* zones (Figure 31). Correlations with conodont zones in the North American Midcontinent areas are discussed about the TAR 1, TAR 2, TPP, ST 1, LAN 1, and LAN 2 sections, because the TUW 1, TUW 2, and TUS sections do not share any biostratigraphically important species with the North American Midcontinent areas.

Section TAR 1

Several species are common to the TAR 1 section and the North American Midcontinent areas. *Teriodon nakamurai*, *Variabiloconus bassleri*, and *Monocostatus sevierensis* have been reported from the Ibexian series in the North American Midcontinent areas (Furnish, 1938; Miller, 1969, 1980; Ethington and Clark, 1971; Repetski, 1982). *Colaptoconus quadriplicatus* has been described from the Low Diversity Interval to the *Oepikodus communis* zones (Ethington and Clark, 1982; Repetski, 1982). Therefore, the *M. sevierensis* and *M. sevierensis - V. bassleri* zones in the TAR 1 section are approximately compared with the Low Diversity Interval to the *O. communis* zones (Figure 31).

Section TAR 2

The TAR 2 section shares its several representative species with North America. *Teriodon nakamurai* and *Variabiloconus bassleri* have been known from the Ibexian series in the North American Midcontinent areas, as previously mentioned. *Rossodus manitouensis* is the nominate species of the *R. manitouensis* zone of in the TAR 2 section and the North American Midcontinent areas (Ethington and Clark, 1971, 1982; Repetski, 1982; Repetski and Ethington, 1983). *Acanthodus lineatus*, which also characterizes the *R. manitouensis* zone in the TAR 2 section, has been reported from the Ibexian series of the North American Midcontinent areas (Furnish, 1938; Ethington and Clark, 1971; 1982). *Colaptoconus bolites* and *Colaptoconus floweri* are representative species of the *R. manitouensis* to Gen. et sp. Indet. 7 zones and the *R. manitouensis* to Gen. et sp. Indet. 7 - *C. floweri* zones in the TAR 2 section, respectively. Repetski (1982) described these species from the Ibexian series in the North American Midcontinent areas, and Ji and Barnes (1994) also reported them from the sequence, which corresponds to the *Diaphorodus deltatus* - *Oneotodus costatus* zone, in Newfoundland. The upper part of the *R. manitouensis* - *T. nakamurai* zone to the Gen. et sp. Indet. 7 zone in the TAR 2 section yields *Colaptoconus quadriplicatus*, which has been described from the Low Diversity Interval to the *Oepikodus communis* zones (Ethington and Clark, 1982; Repetski, 1982). One of the representative species of the Gen. et sp. Indet. 7 zone in the TAR 2 section, *Acodus comptus*, has been reported from the Ibexian series in the North American Midcontinent areas (Branson and Mehl, 1933; Repetski, 1982). Occurrence of *Filodontus filosus* ranges the Low Diversity Interval to the *Reutterodus andius* zone in the North American Midcontinent areas (Ethington and Clark, 1982; Repetski, 1982). These lines of biostratigraphic evidence indicate the following; the *R. manitouensis* zone of the TAR 2 section is compared with the *R. manitouensis* zone in North America; the *R. manitouensis* - *T. nakamurai* zone, the *T. nakamurai* - *V. bassleri* zone, and the Gen. et sp. Indet. 7 zone of the TAR 2 section are equivalent to the Low Diversity Interval to the *O. communis* zone in North America; the Gen. et sp. Indet. 7 - *C. floweri* zone of the TAR 2 section is correlated with the *R. andius* zone in North America (Figure 31).

Section TPP

The *Panderodus nogamii* - *Triangulodus brevinbasis* zone and the *T. brevinbasis* - *Drepanoistodus costatus* zone of the TPP section yields *Juanognathus variabilis* and *Histiodella holodentata*, respectively, which are common species to zones in the North American Midcontinent areas. *J. variabilis* has been reported from the Low Diversity Interval to the *Tripodus laevis* zone in the North American Midcontinent areas (Ethington and Clark, 1982; Repetski, 1982). *H. holodentata* is the index species of the *H. holodentata* zone in the North Amrican Midcontinent areas (Ethington and Clark, 1982). Futhermore, the lowermost occurrence of *P. nogamii*, which ranges throughout the TPP section, is known to be the *T. leavis* zone in the Gondwana areas (Cantrill and Burrett, 2003), although this species has not been reported from North America. To sum up above, the The *P. nogamii T. brevinbasis* zone of the TPP section is correlated with the *T. leavis* zone in the North American Midcontinent area. The *T. brevinbasis* zone and the *T. brevinbasis* - *Drepanoistodus costatus* zone of the TPP section corresponds to the *Histiodella altifrons* to *H. holodentata* zones in the North American Midcontinent area. The uppermost zone of the TPP secion, the *Plectodina onychodonta* zone, may be compared with the *Phragmodus "pre-flwxuosus"* zone, which is above the *H. holodentata* zone in the North American Midcontinent area (Figure 31).

Section LAN 2

The LAN 2 section shares following four species with zones of the North American Midcontinent area; *Cooperiognathus aranda*, *Scolopodus multicostatus*, and *Jumodontus gananda*, which occur from the *C. aranda* zone, and *Scolopodus quadratus*, which is yielded from the *C. aranda* zone and the *S. quadratus* - *C. aranda* zone of the LAN 2 section. *C. aranda* has been described by Ethington and Clark (1982) from the *Reutterodus andinus* to *Tripodus laevis* zones in the North American Midcontinent area. *J. gadanda* and *S. quadratus* (= *Scolopodus rex*, in Repetski, 1982) have been known from the Low Diversity Interval to the *R. andinus* zone (Ethington and Clark, 1982; Repetski, 1982). Ethington and Clark (1982) described *S. multicostatus* from the *Oepikodus communis* zone in the North American Midcontinent area. In other areas, however, this species is known to occur from the sequences, which corresponds to the *O. communis* to the *T. laevis* zones of North America (Stait and Druce, 1993; Zhen et al., 2003c). Therefore, the *C. aranda* zone and the *S. quadratus* - *C. aranda* zone of the LAN 2 section are approximately compared with the *R. andinus* zone and the *T. laevis* zone in the North American Midcontinent area, respectively (Figure 31).

Section LAN 1

Middle Ordovician strata of the LAN 1 section yields *Scolopodus quadratus*, which also occur from the Low Diversity Interval to the *Retterodus andinus* zone in North America, as mentioned above (Ethington and Clark, 1982; Repetski, 1982). However, the Middle Ordovician zones of the LAN 1 section, the Gen. et sp. Indet. 13 zone, the *Drepanoistodus costatus* zone, and the *D. costatus* - *Panderouds nogmaii* zone, are not correlated with zones of North America in detail.

Late Ordovician speices of the LAN 1 section, such as *Scabbardella altipes*, *Baltoniodus variabilis*, *Protopanderodus liripipus*, and *Hamarodus europaeus*, have been reported from North America. Occurrence of *S. altipes* ranges from the *Baltoniodus* sp. cf. *B. variabilis* to *H. europaeus* zones of the LAN 1 section. *H. europaeus* is the representative species of the *H. europaeus* zone in the LAN 1 section. These species occur from the Upper Ordovician sequence, which is equivalent to the *Aphelognathus grandis* to *Aphelognathus divergens* zones in North American (Sweet, 2000). *P. liripipus* is also representative species of the *H. europaeus* zone in the LAN 1 section and has been known from the Middle to Upper Ordovician strata in Yukon and Nuvavut, which correspond to the *Cahabagnathus friendsvillensis* zone to the *A. shetzeri* zone in the North American Midcontinent area (McCracken, 1989). *Baltoniodus variabilis* (= *Prioniodus variabilis*, in Ethington and Schumacher, 1969; Bergström, 1971, 1978) has been reported from the strata, which correspond to the upper *Cahabagnathus sweeti* zone to the *Etismodus quadrudactylus* zone in the North American Midcontinent areas (Ethington and Schumacher, 1969; Bergström, 1971, 1978; Nowlan, 1981). In other areas, occurrence of *S. altipes* ranges throughout Upper Ordovician and *H. europaeus* occurs from the upper Caradocian to Ashgillian (Dzik, 1978, 1994; Orchard, 1980; Trotter and Webby, 1994; Wang et al., 1996; Ferretti and Barnes, 1997; Ferretti and Serpagli, 1999; Wang and Qi, 2001). The Upper Ordovician zones of the LAN 1 section do not share species with those of the North American Midcontinent areas, except for the above two species. To sum up the above faunal evidence, the *B.* sp. cf. *B. variabilis* zone is compared with the upper *Cahabagnathus sweeti* zone to the *Etismodus quadrudactylus* zone in North America. The Gen. et sp. Indet. 12 zone, and the *H. europaeus* zone of the LAN 1 section may be correlated with Upper Ordovician strata in North America (Figure 31).

Section ST 1

One of the stratigraphically important species of the ST 1 section, *Pygodus anserinus*, also has been known from the Middle Ordovician rocks, which is equivalent to the *Cahabagnathus sweeti* zone in the North American Midcontinent area (Bergström, 1971, 1978; Harris et al., 1979). *Sccabbardella altipes*, *Protopanderodus liripipus*, and *Hamarodus europaeus*, which are representative species in the ST 1 section, have been reported from the Middle to Upper Ordovician in North America, as mentioned above. Therefore, the *P. anserinus*, *B.* sp. cf. *B. variabilis*, the *S. altipes* - *H. europaeus*, and *H. europaeus* zone of ST 1 section are approximately compared with the Middle to Upper Ordovician strata, which is younger than the *Cahabagnathus sweeti* zone in the North American Midcontinent area (Figure 31).

6.3 Comparison with Silurian and Lower Devonian conodont biostratigraphy in the world

Aldridge and Schönlaub (1989) compiled the standard biostratigraphy of Silurian conodont as follows; the *Distomodus kentuckyensis*, *Distomodus staurognathoides*, *Pterospathodus celloni*, *Pterospathodus amorphognathoides*, *Ozarkodina sagitta rhenana*, *Ozarkodina sagitta sagitta*, *Ozarkodina bohemica bohemica*, *Ancoradella ploeckensis*, *Polygnathoides siluricus*, *Ozarkodina snajdri*, *Ozarkodina crispa*, *Ozarkodina remscheidensis eosteinhornensis*, and *Icriodus woschmidi woschmidti* zones, in ascending order (Figure 32). According to Uyeno (1990), Lower Devonian conodont biostratigraphy in Canadian Cordillera is following; the *Icriodus woschmidi hesperius*, *Ozarkodina eurekaensis*, *Ancyrodelloides delta*, *Pedavis peravis* zones, in ascending order (Figure 32). Correlation of the Silurian and Lower Devonian zones of the ST 2 and LAN 1 sections in this study are discussed below.

6.3.1 Section ST 2

Most of species, which occur from the *Ozarkodina excavata excavata* zone of the ST 2 section, have relatively long stratigraphic ranges. Among them, occurrence of *Panderodus langkawiensis* is restricted within the *Pterospathodus amorphognathoides* zone. Therefore, the *O. e. excavata* zone of the ST 2 section is compared with the *P. amorphognathoides* zone of the Silurian standard.

6.3.2 Section LAN 1

The LAN 1 section contains several species, which are useful for correlation. *Pterospathodus pennatus proceus* is the nominal species of the *P. p. proceus* zone of the LAN 1 section and has been known from the *Pterospathodus celloni* zone to the *Ozarkodina sagitta rhenana* zone of the Silurian standard (Sweet, 1988; Männik and Aldridge, 1989; Corradini and Serpagli, 1999). Barrick (1977) described *Panderodus langkawiensis* (=*Panderodus sparovi*?), which occurs from the *P. p. proceus* zone and the *Dapsilodus obliquicostatus* zone of the LAN 1 section, from the *P. amorphognathoides* zone. *Dapsilodus sparsus*, which is a representative species of the the *D. obliquicostatus* zone of the LAN 1 section, has been reported from the *P. amorphognathoides* zone to the *Ozarkodina sagitta*

sagitta zone (Barrick, 1977). The *Ozarkodina remscheidensis remscheidensis* zone of the LAN 1 section is characterized by *O. r. remscheidensis* and *Belodella anomalis*. The stratigraphic range of *O. r. remscheidensis* covers from the *Ozarkodina remscheidensis eosteinhornensis* zone to the *Ancyrodelloides delta* zone (Uyeno, 1990; Barrick and Klapper, 1992; Corradini and Serpagli, 1999; Mawson et al., 2003). *B. anomalis* has been known from the *Polygnathoides siluricus* zone to the *Icriodus woschmidi woschmidti* zone (Farrell, 2004). The lower part of the *O. r. remscheidensis* - *Pseudooneotodus beckmanni* zone of the LAN 1 section yields *O. r. eosteinhornensis*, which is an index species of the *O. r. eosteinhornensis* zone of the Silurian standard (Walliser, 1964; Uyeno, 1990; Corradini and Serpagli, 1999; Mawson et al., 2003). *Flajsella stygia* and *Flajsella stigmostygia* occur from the upper part of the *O. r. remscheidensis* - *P. beckmanni* zone of the LAN 1 section. According to Valenzuela-Ríos and Murphy (1997), these species co-occur from the *Ancyrodelloides delta* zone.

These lines of biostratigraphic evidence indicate the following; the *P. p. proceus* zone, the *D. obliquicostatus* zone, and the *O. r. remscheidensis* zone of the LAN 1 section are correlated with the *P. celloni* to *P. amorphognathoides* zones, the *P. amorphognathoides* zone to *O. sagitta sagitta* zones, and the *P. siluricus* zone to *O. r. eosteinhornensis* zones of the Silurian standard, respectively; the *O. r. r.* - *P. beckmanni* zone in the LAN 1 section is compared with the *O. r. eosteinhornensis* to *Ancyrodelloides delta* zones of the Silurian standard and the biostratigraphy conducted in the Canadian Cordillera.

7. SILICICLASTIC BEDS OVERLYING THE ORDOVICIAN AND SILURIAN LIMESTONES

The ST 1 and LAN 1 sections contain siliciclastic beds, overlying the Upper Ordovician and Silurian limestone strata (Figures 16, 18 and 26). These clastic beds do not yield conodonts, but contain graptolites and tentaculites. On the basis of the graptolite and tentaculite biostratigraphy, the ages of these clastic beds are discussed below.

7.1 Age of the siliciclastic beds overlying the Ordovician limestones

Siliciclastic beds overlying the Ordovician limestone in the ST 1 and LAN 1 sections consist mainly of fine-grained sandstone and shale. Black shale samples containing graptolites were collected from the lowermost part of the black shale beds of the ST 1 section (Figures 17 and 33). This graptolite fauna contain at least two species, *Normalograptus pseudovenustus pseudovenustus* (Legrand, 1986) and *Normalograptus* sp. Occurrence of *N. p. pseudovenustus* is limited within the *N. persculptus* zone of uppermost Ordovician (Legrand, 1986) (Figure 33). Wongwanich et al. (1990) also reported two graptolite faunas from this siliciclastic sequence. The lower fauna is yielded from shale beds underlying the sandstone beds of this study and contains *Normalograptus persculptus* (Elles and Wood). However, I could not observe these strata in the field. The upper fauna occurs from the horizon, which is about 8 m above the base of the black shale (Figure 33), and includes *Parakidograptus acuminatus* (Nicholson) and *Climacograptus normalis* (Lapworth). The ages of these fauna are the latest Ordovician and Late Ordovician to Early Silurian, respectively.

Several shale samples, collected from the LAN 1 section of this study, yield numerous graptolites (Figures 27 and 33). However, these specimens could not be identified, due to their poor preservation. Jones (1978) reported four graptolite faunas from the Lower Detrital Member, which corresponds to the siliciclastic sequence of the LAN 1 section in this study. The lowest fauna occurred from the horizon, which is about 1 m above the base of the clastic sequence, contains the species of the *Normalograptus persculptus* zone (Figure 33) (Jones, 1978). The other three faunas occur from the beds between 1 to 5 m below the top of the clastic sequence. These beds are correlated with the *Cystograptus vesiculosus* to *Setimulograptus sedgiwicki* zones (Figure 33) (Jones, 1978).

To sum up above, the ages of the siliciclastic sequences of the ST 1 and LAN 1 sections are as follows. The base of the siliciclastic sequences of the ST 1 section is the uppermost Ordovician, Hirnantian. The age of the top of the siliciclastic sequences of the ST 1 section is younger than Rhudoanian (early Llandovery). The base and top of the siliciclastic sequences of the LAN 1 section are Hirnantian and Aeronian (middle Llandovery), respectively (Figure 33).

7.2 Ordovician - Silurian boundary

Dalmanitina, which is a Hirnantian trilobite, has been reported from the Satun area and the Langkawi Islands. According to Wongwanich et al. (1990), *Dalmanitina* occurs from a sandstone bed, which is correlated with the sandstone of the ST 1 section in this study (Figure 33). In the Langkawi Islands, Jones (1978) reported an occurrence of *Dalmanitina malayensis* Kobayashi and Hamada, 1964a from the horizon about 1.5 m above the base of the silisiclastic beds of the LAN 1 section (Figure 33). To sum up, the Ordovician-Silurian boundary is considered to lie between the horizons of *Normalograptus pseudovenustus pseudovenustus* and upper graptolite fauna of Wongwanich et al. (1990) in the ST 1 section, and to the level directly above the *Dalmanitina* horizon in the LAN 1 section (Figure 33).

7.3 Age of the siliciclastic beds overlying the Silurian limestones

The black shale sequence, which is the upper part of the ST 1 section, yields tentaculites from the horizon about 3 m above the base of the shale (Figure 19). Although this tentaculite bed seems to contain several species of tentaculite, only one species could be identified herein, *Nowakia acuaria* (Richer, 1854). This species has been reported from the Lockhovian to Emsian rocks in Europe, Morocco, and Australia and from Pragian strata in Alaska, northern Africa, and Czechoslovakia (Bouček, 1964; Lardeux, 1969; Churkin and Carter, 1970; Chlupáč and William, 1989). Tentaculite beds in northwestern Malaysia yield many allied species of *Nowakia* (Burton, 1967a) and some of the beds also contain graptolites. Wongwanich et al. (1990) reported several kinds of fossils, including *Nowakia*, *Styliolina*, *Metastyliolina* (tentaculite), *Monograptus* (graptolite), and *Plagiolaria* (trilobite), from the same tentaculite bed of this study. They cited the depositional age of the bed as Early to Middle Devonian. Boucot et al. (1999) also mentioned that this tentaculite bed appear to be late Pragian to earliest Emsian. This tentaculite fauna is similar to that of the Trang area, southern peninsular Thailand, where Kobayashi and Hamada (1968) reported *Nowakia*, *Styliolina*, *Monograptus*, and *Plagiolaria*. On the basis of the graptolites, the fauna of the Trang area is thought to be the earliest Emsian in age (Hamada et al., 1975; Yolkin et al., 1997). In summary, the age of the tentaculite bed in the ST 1 section is earliest Emsian (Figure 34).

Tentaculite beds yielding the *Nowakia* - *Styliolina* fauna have been reported from the following areas of Thailand and Malaysia: the Fang (e.g., Hamada, 1968), Sri Sawat (e.g., Brown et al., 1951), Trang (Kobayashi and Hamada, 1968), and Satun areas of Thailand, the Langkawi Islands (Jones, 1978) and the Mahang and Baling areas (Burton, 1967a; Hamada et al., 1975) of northwestern Malaysia. On the basis of graptolites and trilobites coexisting with tentaculites, Hamada et al. (1975) subdivided the Devonian tentaculite faunas in Thailand and Malaysia into four faunal units, labeled TN 1 to TN 4. They are assigned to Lochkovian, early Emsian, Emsian to Eifelian, and Eifelian ages, respectively (Figure 34). The TN 1 fauna corresponds to the fauna of the Langkawi Islands. The TN 2 fauna is known from the Fang, Sri Sawat, Trang, and Baling areas. The TN 3 fauna occurs in the Trang and Baling areas. The TN 4 fauna is correlated with a part of the tentaculite beds in the Fang and Sri Sawat areas (Hamada et al., 1975). The tentaculite bed in the ST 1 section is compared with that of the Trang area, which is earliest Emsian, as stated above. Therefore, the tentaculite bed in the present study belongs to TN 2 (Figure 34).

Siliciclastic beds overlies the Silurian to Lower Devonian limestone sequence of the LAN 1 section (Figure 26). I could not obtain any fossils from this clastic beds. However, on the basis of lithostratigraphic correlations, the silicislastic beds in the LAN 1 section is equivalent to the black shale beds, which are the upper part of the ST 1 section (Wongwanich et al., 1990).

7. 4 Silurian - Devonian boundary

On the basis of the conodont biostratigraphy, the *Ozarkodina remscheidensis remscheidensis* - *Pseudooneotodus beckmanni* zone, which is the uppermost part of the limestone sequence of the LAN 1 section, contains the Silurian - Devonian boundary (Figure 27). The conodnot and tentaculite biostratigraphy indicates that the limestone and black shale strata in the ST 2 section are Llandovery of Lower Silurian and Emsian of Lower Devonian, respectively. Although the boundary of the limestone and black shale of the ST 2 section is not exposed, the Silurian - Devonian boundary may lie in the uppermost part of the limestone sequence, as well as the LAN 1 section.

On the basis of the above discussions on the conodont, graptolite, and tentaculite biostratigraphy, all of the sections in the study areas are arranged in Figure 35.

8. PALEOBIOGEOGRAPHY

Conodonts exhibit strong provincialism during the Ordovician time (Bergström and Sweet, 1966; Barnes and Fåhraeus, 1975). I have attempted to discuss on paleobiogeography of the Ordovician conodonts from the studied sections. Sweet et al. (1959) suggested that Ordovician conodont distribution can be separated into the North American and North Atlantic areas. This provincialism distinguishes the North American Midcontinent and North Atlantic Provinces (Barnes et al., 1973). The North American Midcontinent Province includes the western Appalachian areas and the Canadian Arctic Archipelago. The North Atlantic Province mainly consists of northwestern Europe, the British Isles, and the eastern Appalachian areas. Sweet and Bergström (1984) suggested that the conodont faunas distributed in the North American Midcontinent and North Atlantic Provinces represent "warm-water" and "cool-water" faunas, respectively. Conodont faunas of the North American Midcontinent type are consistently associated with lithologic features that suggest depositional environment generally above 15°C, and paleomagnetic evidence indicates that these strata accumulated in the low latitudes within 25-30° from the Ordovician equator (Bergström, 1973; Sweet and Bergström, 1974, 1984). On the other hand, North Atlantic conodont faunas were distributed typically in areas that were situated above 40° parallel and in the peri-cratonic areas of low-latitude continents (Sweet and Bergström, 1984). Those peri-cratonic strata including the North Atlantic faunas are exposed in areas from eastern Appalachian to Newfoundland in North America (Bergström, 1971; Stouge, 1984; Stouge and Bagnoli, 1988; Fåhræus and Roy, 1993; Ji and Barnes, 1994; Pohler, 1994; Johnston and Barnes, 1999, 2000) and these strata accumulated in a deeper- and cooler-water environment than those of the North American Midcontinent areas.

Conodont faunas both of the North American Midcontinent and North Atlantic Provinces have been reported from the Gondwana areas, including Australia, North and South China, and Argentina (Serpagli, 1974; Cooper, 1981). Bergström (1971) first suggested the existence of an Australasian Province. In addition, an Australasian or Gondwanan Province were proposed based on the distribution of several endemic conodonts, such as *Taoqupognathus* and *Yaoxianognathus* (Nicoll and Webby, 1996; Nowlan et al., 1997). Nicoll and Metcalfe (2001) suggested that several Ordovician conodonts defined the East Asia-Australasia Province, which is characterized by *Serratognathus* and *Aurilobodus* in Early Ordovician, *Plectodina onychodonta* and *Tasmanognathus* in Middle Ordovician, and *Taoqupognathus* and *Yaozianognathus* in Late Ordivician. The distributions of these conodonts are principally restricted in Australia and North and South China.

8.1 Early Ordovician conodonts

Early Ordovician conodonts mainly occur from the TAR 1 and TAR 2 sections and the lower part of the TPP and LAN 2 sections. Some species of TAR 1 and TAR 2 sections, *Variabiloconus bassleri*, *Monocostatus sevierensis*, *Rossodus manirouensis*, *Acanthodus lineatus*, *Colaptoconus quadraplicatus*, *Parapanderodus striatus*, *Colaptoconus bolites*, and *Colaptoconus floweri*, have been known from the North American Midcontinent areas and the North American deeper-water sequences (Branson and Mehl, 1933; Landing, 1976; Furnich, 1938; Ethington and Clark, 1982; Repetski, 1982; Repetski and Ethington, 1983; Nowlan, 1985; Landing et al., 1986; Stouge and Bagnoli, 1988; Fåhræus and Roy, 1993; Johnston and Barnes, 1999, 2000; Landing et al., 2003). *Scolopodus transistans* from the TAR 1 section has been described only from Australia (Jones, 1971; Zhen et al., 2003c). The lower part of the TPP section yields *Juanoganthus variabilis*, which has been reported from the Gondwana areas, including China, Australia, and Argentina, and the North American deeper-water sequences, such as Newfoundland (Serpagli, 1974; Johnston and Barnes, 1999, 2000; Zhen et al., 2003b, 2003c). *Panderodus nogamii*, which occurs from the TPP and LAN 2 sections, is restricted its distribution in the Gondwana areas (Cantrill and Burrett, 2003). To sum up above, the Early Ordovician conodont faunas of the study areas are closely related to the North American Midcontinent fauna and the North American deeper-water fauna throughout Early Ordovician. Faunal affinity between the study areas and other Gondwana areas is also recognized. Although *Serratognathus*, which defines the Early Ordovician East Asia-Australasia Province (Nicoll and Metcalfe, 2001), is not found from the studied sections, Metcalfe (1980) reported *Serratognathus bilobatus* Lee, 1970 from the Setul Limestone in the Peris area, peninsular Malaysia. To sum up, the Shan-Thai Block, where the study areas were sited, was situated near Australia, North China, and South China in the East Asia - Australasia Province, which was in the low latitudes together with the North American Midcontinent areas, in Early Ordovician (Figure 36).

8.2 Middle Ordovician conodonts

The TUS, TUW1, and TUW 2 sections, the middle to upper part of the TPP section, the upper part of the LAN 2 section, and the lower part of the LAN 1 section in the study areas contain the Middle Ordovician conodonts. According to Nicoll and Metcalfe (2001), species of *Aurilobodus* and *Plectodina ohychodonta* are representatives of the East Asia - Australasia Province. Species of *Aurilobodus* occur from the TPP, LAN 1, and LAN 2 sections. *Plectodina ohychodonta* is contained in the upper part of the TPP section. *Triangulodus larapintinensis* is an Australian endemic species and occurs from the TPP, LAN 1 and LAN 2 sections. *Histiodella holodentata*, which characterizes the upper part of the TPP section, is a typical species of the North American Midcontinent Province. This species also has been known from Australia and North China (Ethington and Clark, 1982; Watson, 1988; Wang et al., 1996; Johnstone and Barnes, 1999, 2000). The TPP, TUS, LAN 1, and LAN 2 sections yield endemic species of Gondwana, such as *Panderodus nogamii* and *Drepanoistodus costatus* (Cooper, 1981; Stait and Druce, 1993; Zhen et al., 2003b). *Cooperignathus aranda*, *Cooperignathus nyinti*, *Jumodontus gananda*, and species of *Bergstroemognathus* are common in faunas of the North American deeper-water areas, North China, and Australia (Wang et al., 1996; Zhen et al., 2003b, 2003c). The TUW 1 section contains a typical North Atlantic species, *Walliserodus costatus*. These lines of biostratigraphic evidence suggest the following; the Shan-Thai Block lay within the East Asia - Australasia Province during Middle Ordovician; the Middele Ordovician conodont faunas of the study areas are closely related to those of Australia, North China, and the North American deeper-water areas; typical species both of the North American Midcontinent and the North Atlantic Provinces are found from the sections in this study areas, as well as other Gondwana areas.

8.3 Late Ordovician conodonts

Late Ordovician conodonts occur from the ST 1 and LAN 1 sections in this study areas. These faunas contain representative species of the North Atlantic Province, *Scabbardella altipes*, *Dapsilodus mutatus*, *Protopanderodus liripipus*, and *Hamarodus europaeus*. These species are common in the North Atlantic areas, the North American deeper-water areas, Australia, and South China (Trotter and Webby, 1994; Wang et al., 1996; Ferretti and Serpagli, 1999; Zhen et al., 1999; Sweet, 2000). Sweet and Bergström (1984) recognized several biofacies of the Late Ordovician conodonts in the North American and North Atlantic areas. According to Sweet and Bergström (1984), the low-latitude North American Midcontinent Province in Late Ordovician is characterized by warm-water and cool-water faunas. Totally six biofacies, controlled by water temparature, salinity, turbidity, and other depth-related environmental factors, were distinguished in these faunas; the *Dapsilodus mutatus - Periodon grandis* biofacies, the *Amorphognathus superbus - Amorphognathus ordovicicus* biofacies, the *Phragmodus* biofacies, the *Plectodina* biofacies, the *Pseudobelodina* biofacies, and the *Aphelognathus - Oulodus* biofacies (Sweet and Bergström, 1984). On the other hand, the high-latitude North Atlantc Province in Late Ordovician is characterized by four distinct biofacies, the *Hamarodus europaeus - Dapsilodus mutatus - Scabbardella altipes* (HDS) biofacies, the *Phragmodus undatus - Icriodella- Plectodina* biofacies, the *Amorphognathus - Plectodina* biofacies, and the *Sagittodontina robusta - Scabbardella altipes* biofacies (Sweet and Bergström, 1984). Distributions of these biofacies were probably defined by the local environmental conditions, for example water depth and temparature (Sweet and Bergström, 1984). The HDS biofacies shows high frequencies of *H. europaeus* (occupies about 40% of numbers of elements in a conodont fauna, which occur from one horizon) and *D. mutatus* (35% - 40%), and commonly contains *S. altipes* and *Amorphognathus*. Other common taxa of this biofacies are *Panderodus* and *Protopanderodus liripipus*. The ratio of these taxa and kinds of other additional species depend on areas. The representatives of the *P. undatus - Icriodella- Plectodina* biofacies are *Panderodus* and other conodonts with coniform elements, in addition to *P. undatus*, *Icriodella* and *Plectodina*. The *Amorphognathus - Plectodina* biofacies is characterized by high frequencies of *Plectodina*, *Panderodus*, *Amorphognathus*, *Rhodesognathus*, and *Icriodella*. The *S. robusta - S. altipes* biofacies is dominated by *S. robusta*, *S. altipes*, *Amorphognathus*, and *Istorinus*. This biofacies is distributed in the Mediterranean area, including Thuringia, Spain, Libya, and northwest France, and occupied the position closest to the pole (Sweet and Bergström, 1984; Ferretti and Serpagli, 1999). The Upper Ordovician *H. europaeus* zones in the ST 1 and LAN 1 sections in this study are characterized by the high frequencies of *H. europaeus*, *D. mutatus*, *S. altipes*, and *P. liripipus*. Figure 37 shows the proportion of element number of these species in the total number of elements, which occur from each horizon of the *H. europaeus* zones in the ST 1 and LAN 1 sections. *H. europaeus*, *D. mutatus*, *S. altipes*, and *P. liripipus* occupy on average 19%, 6%, 70%, and 3 % numbers of elements in the conodont faunas from the ST 1 section, respectively. In the LAN 1 section, the average frequencies of these species are 27% (*H. europaeus*), 16% (*D. mutatus*), 37% (*S. altipes*), and 10% (*P. liripipus*). These species are associated with rare elements of species of *Amorphognathus*, *Panderodus*, and *Ansella*. These faunas of the *H. europaeus* zones in the ST 1 and LAN 1 sections in this study are close to the HDS biofacies in the North Atlantic Province. The faunas in this study have regional characteristics that *S. altipes* is a dominant component and that species of *Amorphognathus* are rarely contained. According to Sweet and Bergström (1984) and Ferretti and Serpagli (1999), the HDS biofacies appears to be widespread in the Baltic, British, and

Mediterranean areas of the North Atlantic Province, and suggests that these areas were situated in middle to high latitude (Figure 36).

The representatives of the Upper Ordovician East Asia - Australasia Province are *Taoqupognathus* and *Yaoxianognathus* (Nicoll and Metcalfe, 2001). However, these taxa do not occur from the ST 1 and LAN 1 sections in this study.

To sum up the above faunal evidence, the paleobiogeography of the Shan-Thai Block, where the study areas were sited, is interpreted as follows. The Shan-Thai Block has been situated in the East Asia - Australasia Province, which occupied a low-latitude area, during Early to Middle Ordovician (Figure 36). Subsequently, the Shan-Thai Block moved to the higher latitudes in late Middle Ordovician. The conodont faunas of the Shan-Thai Block changed from the representatives of the East Asia - Australasia Province to that of the North Atlantic Province. In Late Ordovician, the Shan-Thai Block reached the middle to high latitudes, where the Baltic, British, and Mediterranean areas were also situated (Figure 36).

9. DEPOSITIONAL ENVIRONMENT

Based on field observations and thin section analyses, the depositional environments of the study areas are here inferred. The reconstructed paleoenvironments and the sea-level changes of each section are showed in Figures 4, 8, 11, 13, 16, 18, 21, 23, 26, and 28. The depositional environments of the study areas are approximately divided into two types. One is a relatively deeper water environment spreading around the border between Thailand and Malaysia, and is well represented as the limestone and siliciclastic sequences of the TAR 2 and LAN 1 sections. I term this area the Tarutao - Langkawi area temporarily. The other is shallow-water environment, which existed in the Thong Pha Phum area, western Thailand. The TPP section, represented by a shallow-water environment, ranges only a short stratigraphic interval, uppermost Lower Ordovician to upper Middle Ordovician. The following is the discussion of the paleoenvironments and the sea-level changes of the Tarutao - Langkawi area and the Thong Pha Phum area. Discussions of depositional environments of carbonate rocks are based on the models by Walker (1979), Tucker and Wright (1990), and Scholle et al. (1991).

9.1 Lower Ordovician in the Tarutao - Langkawi area

The TAR 2 section consists of the Lower Ordovician strata (Figures 23 and 24). The limestone facies of the lower part of the *R. manitouensis* zone, the lowermost part of the TAR 2 section, suggests that its depositional environment was on a shelf under high-energy conditions where terrigenous grains were continually provided. The environment changed to a deeper-water shelf by a transgression and this condition continued until late Tremadocian. The limestones of the upper part of the *R. manitouensis* zone and the *R. manitouensis* - *T. nakamurai* zone accumulated under this environment. The interbeds of shale and limestone, which are main strata of the *T. nakamurai* - *Variabiloconus bassleri* and Gen. et sp. Indet. 7 zones, indicate a low sea level interval, which started with a regression of late Tremadocian and ended with a transgression of early Arenigian. This interval was characterized by inflows of a large amount of terrigenous materials and strong currents, which form cross laminations. The alternation of limestone and shale suggests some cyclic changes of environment factors, such as a depth, salinity, temperature, and turbidity. These factors may more or less have been influenced by transgressions and regressions. The upper part of the TAR 2 section is thought to have been deposited under deeper-water conditions, which is similar to that the gray limestone beds in the lower part of this section (Figure 23).

The TAR 1 section and the lower part of the LAN 2 section also consist of the Lower Ordovician rocks. On the basis of the conodont biostratigraphy, these sequence is correlated with the upper part of the *R. manitouensis* - *T. nakamurai* zone and the Gen. et sp. Indet. 7 - *Colaptoconus floweri* zone of the TAR 2 section, respectively. The depositional environments of the TAR 1 and LAN 2 sections agree with those of the equivalent strata of the TAR 2 section (Figures 21 and 28).

9.3 Middle to Upper Ordovician in the Tarutao - Langkawi area

The lower part of the LAN 1 section is the Middle to Upper Ordovician succession. The lower part of the TUW 2 section and the upper part of the LAN 2 section are correlated with the Middle Ordovician strata of the LAN 1 section. The Upper Ordovician sequences of the ST 1 and LAN 1 sections are compared each other. Based on the limestone facies, the depositional environment of the lowermost part of the LAN 1 section, which is correlated with the Gen. et sp. Indet. 13 zone to the lower part of the *Drepanoistodus costatus* zone, were on middle or outer shelf (Figures 26 and 27). The limestone facies of the TUW 2 and LAN 2 sections suggest that the depositional environments of these sections were similar to the lithofacies of the the Gen. et sp. Indet. 13 zone to the lower part of the *Drepanoistodus costatus* zone of the LAN 1 section (Figures 13 and 28).

The strata with slumping structures of the upper part of the *D. costatus* zone of the LAN 1 section imply the beginning of a transgression in late Arenigian to early Darriliwian (Figure 26). The depositional environment of the LAN 1 section continued to subsiding and settled in a hemipelagic condition in middle Darriwilian. The strata of the upper part of the *D. costatus* - *Panderodus nogamii* zone to the *Hamarodus europaeus* zone of the LAN 1 section are characterized by the nodular limestone. According to Scholle et al. (1991) the nodular limestone is formed by diagenesis on a hemipelagic sea floor. These limestone of the LAN 1 and ST 1 sections yield abundant macrofossils and Wongwanich et al. (1990) reported pelagic trilobites from the ST 1 section. These facts demonstrate that the nodular limestones were deposited on comparatively pelagic environment, such as slope to basin (Figures 16 and 26). This condition extended from early to late Caradocian. Uppermost Ordovician of the LAN 1 and ST 1 sections are hemipelagic siliciclastic sequences overlying the nodular limestone. The fine-grained sandstone bed of the ST 1 section suggests a brief regression in Hirnantian (Figures 16 and 26).

9.4 Silurian to Devonian in the Tarutao - Langkawi area

The Silurian to Devonian sequences are preserved in the ST 2 and LAN 1 sections. The lowermost shale beds of the Silurian strata in the LAN 1 section imply that the hemipelagic depositional environment of the latest Ordovician continued until late Aeronian (Early Silurian) (Figure 33). Limestone sedimentation resumed at least in Telychian (Early Silurian).This limestone is thought to have been deposited under an equable condition during Silurian (Figure 26). Any data, indicating a depositional depth of the Silurian limestones, were not found from the studied section. I temporarily mention that the Silurian limestone accumulated on slope to basin, because the facies of the Silurian limestone is quiet similar to that of the uppermost part of the Ordovician limestone in the LAN 1 section, under a microscopic observation (Figure 26). This condition continued until Early Devonian.

On the basis of the conodont biostratigraphy, the Silurian strata of the ST 2 section is correlated with the *Pterospatnodus pennatus proceus* to *Dapsiodus obliquicostatus* zones of the LAN 1 section. The depositional environments of the ST 2 sections coincide with those of the equivalent strata of the LAN 1 section (Figures 19 and 26).

Siliciclastic deposition replaced the limestone accumulation in Early Devonian. The facies of the Lower Devonian shale in the LAN 1 and ST 2 sections suggest that the depositional environments of these shales were relatively pelagic environment, such as slope to basin (Figures 19 and 26).

9.5 Lower to Middle Ordovician in the Thong Pha Phum area

The lithofacies of the uppermost Lower Ordovician to the upper Middle Ordovician strata in the TPP section differ from the Lower to Middle Ordovician sequences in the Tarutao - Langkawi areas as stated above. The lowermost limestone of the TPP section, which corresponds to the lower to middle part of the *Panderodus nogamii - Triangulodus brevibasis* zone, deposited on middle shelf under high-energy condition (Figure 5). The limestone and sandstone sequence ranging from the upper part of the *P. nogamii - T. brevibasis* zone to the middle part of the *T: brevibasis* to *Drepanoistodus costatus* zone accumulated under back shoal and sand shoal conditions and represents a low sea level interval. This interval began with an earliest Middle Ordovician regression and ended with an early Darriwilian transgression. Subsequently to this transgression, the depositional environment of the limestones of the TPP section changed to a deeper-water condition, such as middle to outer shelf. The deepening progressed during middle Darriwilian (Figure 5).

9.6 Sea-level change in the study areas

The sea-level curves in the Tarutao - Langkawi and Thong Pha Phum areas are shown in Figure 38. Several conspicuous transgression and regression events are recognized in these areas, the late Tremadocian regression, the earliest Middle Ordovician regression, and the late Arenigian to early Darriliwian transgression. The characteristics of the sea-level curves in the study areas, including these three events, are discussed below.

On the basis of the conodont biostratigraphy, the late Tremadocian regression event, which is repoded in the TAR 2 section, is correlated with the global sea level fall (Fortey, 1984; Albanesi and Bergström, 2004) . This regression is represented in a deeper-water facies by oxidized sediments in the Cow Head Group of western Newfoundland (Stouge and Bagnoli, 1988) and in shallow-water sequences of North America by hiatus (Ross and Ross, 1995). Nicoll et al. (1992) recognized the hiatus as the "Kelly Creek Eustatic Event" in Australia. This event is compared with the " Ceratopyge Regressive Event" in Scandinavia (Nielsen, 2004) (Figure 38).

The TPP section records the earliest Middle Ordovician regression, which is correlated with a global regression event (Barnes, 1984; Fortey, 1984; Ross and Ross, 1995; Albanesi and Bergstorom, 2004). In North America, the Ibexian - Whiterockian boundary are defined by a pronounced extinction event, which is related to the global regression (Figure 38). This sea-level change does not observed in the Middle Ordovician sequences of the LAN 1, LAN 2, and TUW 2 sections in the Tarutao - Langkawi area. This is probably caused by their depositional environments, which were deeper water than that of the TPP section.

The late Arenigian to middle Darriliwian transgressive sequence is represented in the LAN 1 section. Middle Ordovician in North America and the Baltoscandia areas does not preserve sediments indicating a marked transgression. However, the deepening facies of the Arenigian to Darriwilian have been reported from the Argentine Precordillera and the northern margin of the Yangtze Platform, South China (Chen and Barnes, 1995; Albanesi et al., 1999; Albanesi and Bergström, 2004). The Middle to Upper Ordovician in the Argentine Precordillera and the northern margin of the Yangtze Platform are partly characterized by nodular limestone resembling that of the LAN 1 section, and show the high sea level intervals (Chen and Barnes, 1995; Albanesi and Bergström, 2004) (Figure 38). Therefore, the late Arenigian to early Darriliwian transgression and the subsequent deeper-water condition of the LAN 1 section are the regional characteristics common to the peri-platform areas of Gondwana. The transgression is also recorded in the TPP section of the Thong Pha Phum area, where the depositional environment was shallower-water on a shelf. However, a sea-level change of a shallow-water condition after Late Ordovician can not be inferred due to an absence of data.

Most of Hirnantian (Latest Ordovician) sequences in the world show the evidence of the regression, reflecting glacio-eustatic sea-level changes (Brenchley, 1988, 2004). Brenchley (1988) illustrates the Hirnantian shallowing facies in a glaciomarine, clastic, and carbonate environments. For example, on a clastic shelf, mudstone grades upward into a shallow marine sand facies. The fine-grained deposits of a clastic basin usually change to channel-fill, debris flow, and submarine fan sediments. The fine-grained sandstone bed of the uppermost part of the ST 1 section does not show a large-scale influx of clastics from a shelf. The siliciclastic sequences of the uppermost Ordovician in the LAN 1 and ST 1 sections suggest that the depositional basins of these sections were isolated from the source of coarse clastics and the fluctuation of the sea level did not largely affect the basin (Figure 38).

10. SUMMARY

(1) The Lower Ordovician to Lower Devonian conodont zones are established in the Thong Pha Phum area, western Thailand, the Thung Song, Thung Wa, and Satun areas and Tarutao Island, southern peninsular Thailand, and the Langkawi Islands, northern peninsular Malaysia. On Tarutao Island, the following seven Lower Ordovician zones are built up; the *Monocostodus sevierensis* range zone and the *M. sevierensis serierensis* - *Variabiloconus bassleri* interval zone, in ascending order, in the TAR 1 section; the *Rossodus manitouensis* range zone, the *R. manitouensis* - *Teriodon nakamurai* interval zone, the *T. nakamurai* - *V. bassleri* interval zone, Gen. et sp. Indet. 7 range zone, and Gen. et sp. Indet. 7 - *Colaptoconus floweri* interval zone, in ascending order, in the TAR 2 section. In the Thong Pha Phum area, the four Lower to Middle Ordovician zones are established in the TPP section; the *Panderodus nogamii* - *Triangulodus brevibasis* interval zone, the *T. brevibasis* range zone, the *T. brevibasis* - *Drepanoistodus costatus* interval zone, and the *Plectodina onychodonta* assemblage zone, in ascending order. In the Thung Wa area, the following two Middle Ordovician zones, the *Periodon aculeatus* range zone and the *Protopanderodus gradatus* range zone, are made up in the TUW 2 and TUW 1 sections, respectively. In the Thung Song area, the Middle Ordovician *Panderodus nogamii* range zone is established in the TUS section. The following five Middle Ordovician to Lower Silurian zones are built up in the Satun area; the *Pygodus anserinus* range zone, the *Baltoniodus* sp. cf. *B. variabilis* range zone, the *Scabbardella altipes* - *Hamarodus europaeus* interval zone, and the *Hamarodus europaeus* range zone, in ascending order, in the ST 1 section; the *Ozarkodina excavata excavata* range zone in the ST 2 section. In the Langkawi Islands, the twelve Lower Ordovician to Lower Devonian zones are set up; the Gen. et sp. Indet. 13 range zone, the *D. costatus* range zone, the *D. costatus* - *Panderodus nogamii* interval zone, the *B.* sp. cf. *B. variabilis* range zone, the Gen. et sp. Indet. 12 range zone, the *H. europaeus* range zone, the *Ozarkodina pirata* range zone, the *Dapsilodus obliquicostatus* range zone, the *Ozarkodina remscheidensis remscheidensis* range zone, and the *O. r. remscheidensis* - *Pseudooneotodus beckmanni* interval zone, in ascending order, in the LAN 1 section, and the *Scolopodus quadratus* range zone and the *Cooperignathus aranda* range zone, in ascending order, in the LAN 2 section.

(2) On the basis of the conoodont and graptolite biostratigraphy, the Ordovician - Silurian boundary is

recognized in the siliciclastic sequences of the ST 1 and LAN 1 sections. The conodont and tentaculite biostratigraphy suggests that the Silurian - Devonian boundary is defined in the uppermost limestone strata of the LAN 1 section and may be lie between the lower limestone and upper shale sequences in the ST 2 section.

(3) Depositional environments of the Lower to Middle Ordovician strata in the study sections are distinguished into two types, the shallow-water shelf to sand shoal conditions in the Thong Pha Phum area and the relatively deeper water shelf to basin conditions in the Tarutao - Langkawi area. The late Tremadocian regressions in the Tarutao - Langkawi area is correlated with the global sea level fall, recorded as "Kelly Creek Eustatic Event" in Australia and "Ceratopyge Regressive Event" in Scandinavia. The earliest Middle Ordovician regression is recognized in the shallow-water strata in the Thong Pha Phum area. This is parallel to the global regression event, which is related to the Lower and Middle Ordovician boundary. The upper Arenigiand to middle Darriwilian sequences both of the Tarutao - Langkawi and Thong Pha Phum areas represents a transgression event, which is compared with a regional sea level rise in the northern Gondwana. The hemipelagic environment in the Tarutao - Langkawi area continued up to Early Devonian. The glacio-eustatic sea-level change, which is found in the most of the uppermost Ordovician sequences in the world, do not have a great influence to the depositional environment of the study areas.

(4) On the basis of the correlations between the Ordovician conodonts from the study areas and those of the Australia, North and South China, North Atlantic, and North America, the Early to Middle Ordovician faunas and the Upper Ordovician faunas from the study areas belong to the East Asia - Australasia Province and the North Atlantic Province, respectively. This faunal change took place following the Arenigian to Darriwilian transgression in northern Gondwana. The Caradocian conodont fauna from the study areas is compared with one of the typical conodont biofacies of the North Atlantic Province, *Hamarodus europaeus - Dapsilodus mutatus - Scabbardella altipes* biofacies. This biofacies had been distributed in the middle to high latitudes in Late Ordovician.

(5) The paleogeography of the Shan-Thai Block and the depositional environments of the study areas are interpreted as follows. The Lower to Middle Ordovician rocks in the study areas accumulated on a shelf of the Shan-Thai Block, which had been situated near Australia and North and South China in the low latitudes. The limestone and sandstone sequence in the Thong Pha Phum area was

deposited on a shallow-water shelf close to a land. The limestone and fine-grained clasitic rock sequences in the Tarutao - Langkawi area were formed on a deeper-water shelf than the depositional environment of the Thong Pha Phum area. The regional transigression proceeded during late Arenigin to middle Darriwilian, and conodont faunas changed from the East Asia - Australasia fauna to the North Atlantic fauna. The Shan-Thai Block moved to the higher latitudes until Caradocian. The hemipelagic environment of the Tarutao-Langkawi area extended into Early Devonian.

(6) Ninety five belonging to 50 genera and 22 unidentified species of Early Ordovician to Early Devonian conodonts are systematically investigated and illustrated. Two species of Late Ordovician graptolites and 1 species of Early Devonian tentaculites are also systematically investigated.

SYSTEMATIC PALEONTOLOGY

CONODONTS

All specimens described in this paper are deposited in the Institute of Geoscience, University of Tsukuba, with the prefix IGUT. Conodont taxa herein are only classified to genus and species. Genera and species are listed in alphabetical order. Element terminology basically follows that of Barnes et al. (1979). Class is from Sweet (1988).

Class **Cavidonti** Sweet, 1988

Genus ***Ansella*** Fåhræus and Hunter, 1985

Type species.--*Belodella jemtlandica* Löfgren, 1978.

Remarks.--Several authors have proposed morphotypes of *Ansella* elements (e.g. Löfgren, 1978; Fåhræus and Hunter, 1985; Watson, 1988; Sweet, 1988). I use here the concept of Fåhræus and Hunter (1985). They wrote that species of the genus are composed of nondenticulate plano-convex to biconvex coniform elements, plano-convex coniform elements with denticles along upper posterior margin of base, symmetrical bicostate denticulate coniform elements, and geniculate nondenticulate elements.

Ansella jemtlandica (Löfgren, 1978)

Plate 45: 11-13

Belodella jemtlandica Löfgren, 1978, p. 46-49, pl. 15, fig. 1-8, text-fig. 24: a-d; Stouge, 1984, p. 60, pl. 6, figs. 13-23, pl. 7, figs. 1-4.

"Belodella" sp. A Serpagli, 1974, p. 38, 39, pl. 8, fig. 7, pl. 20, fig. 10.

Ansella jemtlandica (Löfgren, 1978). Fåhræus and Hunter, 1985, p. 1173-1175, pl. 1, figs. 1-5, 9, pl. 2, fig. 12, text-fig. 1; Bauer, 1989, p. 98, fig. 4: 4, 6, 10; Pohler, 1994, pl. 1, figs. 15, 16; Albanesi, 1998b, p. 160, 161, pl. 1, figs. 18-23, text-fig. 27.

Material examined.--Twenty two specimens; 6 *a*, 3 *b*, 6 *c*, 5 *e*, and 2 *f* elements (Figured specimens are listed here with IGUT number; IGUT-ag2066 to 2068).

Occurrence.--Beds LAN-8 to 10, 27, 28, 31, 33, 79, and 80 in the LAN 1 section.

Remarks.--Löfgren (1978) described adenticulate biconvex, denticulate plano-convex, denticulate triangular, and oistodontiform elements, consisting the apparatus of this species. Fåhræus and Hunter (1985) recognized two types of denticulate triangular elements, which are symmetrical and asymmetrical elements. Their denticulate elements occupy *a*, *b*, and *c* positions in apparatus and form a symmetry transition series. Oistodontiform and adenticulate elements of Löfgren (1978) and Fåhræus and Hunter (1985) correspond to *e* and *f* elements, respectively (Albanesi, 1998b). Collection of this study contains every type of elements.

***Ansella* sp. A**

Plate 47: 3

Description.--Element has proclined cusp forming 90-120°with posterior margin of base. Posterior margin is compressed and finely denticulated at base. Unit has distinct anterolateral costae bordering flat anterior face. Basal margin is triangular with anterolateral and posterior edges in aboral view.

Material examined.--One specimen; 1 *c* element (IGUT-ag1158).

Occurrence.--Bed ST-4 in the ST 1 section.

Remarks.--Specimen is bilaterally symmetrical and assigned to *c* element in apparatus of this genus. However, identificatoin of species is difficult due to a lack of other elements.

***Ansella* sp. B**

Plate 47:1, 2

Description.--Element is proclined and has slim cusp and expanded, long base. Unit twists toward inner side and has keeled anterior margin. Base is laterally compressed and denticulated on posterior margin. Outline of basal margin is elliptical with sharply pointed anterior and posterior ends in aboral view.

Material examined.--Three specimens; 3 *a* elements (IGUT-ag1649, 1770).

Occurrence.--Beds ST-9, 10, and 18 in the ST 1 section.

Remarks.--Specimens are asymmetrical elements with lenticular cross-section at base. These characteristics suggest that the specimens are *a* elements.

***Ansella* sp. C**

Plate 40: 2, 3

Description.--Symmetrical bicostate element and geniculate elements occur from the study section.

These elements correspond to *a* and *e* element in apparatus of this genus, respectively. *C* element has erect cusp and antero-posteriorly expanded base. Posterior margin is compressed and finely denticulated at base. Cross-section is lenticular at base. *E* element is laterally compressed with sharply edged anterior and posterior margins. Cusp inwardly twists. Upper margin of base is strongly compressed and meets basal margin at 30°. Anterior and basal margins form an angle approximately 90°. Basal margin is downwardly convex in lateral view.

Material examined.--Three specimen; 1 *a* and 2 *e* elements (IGUT-ag2020 to 2021).

Occurrence.--Bed TPP-18 in the TPP section.

Remarks.--Above-mentioned characteristics of *a* and *e* elements suggest that these specimens are components of apparatus of this genus. However, identification of species is difficult due to a lack of other elements.

***Ansella* sp. D**

Plate 40: 13

Description.--Element is subsymmetrical bicostate form with proclined cusp. Anterior face is widely flattened and edged by sharp anterolateral costae on each side. Base is laterally compressed and triangular in lateral view. Fine denticles are developed on posterior margin. Basal cavity sharply tips near anterior margin.

Material examined.--Two specimen; 2 *b/c* elements (IGUT-ag2031).

Occurrence.--Bed TPP-27 in the TPP section and bed LAN-77 in the LAN 2 section.

Remarks.--Specimens are characterized by extremely fine denticulation of the posterior margin and relatively wide anterior face of base. Base is short compared with other denticulated elements in the collection of this study.

Genus ***Belodella*** Ethington, 1959

Type species.--*Belodus devonicus* Stauffer, 1940.

Remarks.--Barrik and Klapper (1992) suggested that *a*, *b*, *c*, *d*, *e*, and "*t*" elements are components of apparatus of this genus. The *a*, *b*, *c*, and *d* elements form a symmetry transition series.

Belodella anomalis Cooper, 1974

Plate 53: 1, 2

Belodella anomalis Cooper, 1974, p. 1121, pl. 1, figs. 2-10, text-fig. 1; Cooper, 1978, fig. 3; Jeppsson, 1989, p. 25, pl. 1, fig. 15; Anderson, 2003, pl. 3, fig. 13-17, 19-21, 24-26; Farrell, 2003, pl. 1, figs. 6, 7; Farrell, 2004, p. 949-952, pl. 1, figs. 1-17. text-fig. 4.

Description.--Asymmetrical and laterally compressed *d* and "*t*" elements are identified. *D* element has erect cusp, which lacks developoment of denticulation. Cross-section is modified lenticular at base. Anterior margin of base is pinched and forming a flattened area. The anterior edge is denticulated. Posterior margin is also finely denticulated. "*T*" element has proclined cusp and slender base. Cusp is lenticular in cross-section and inclines to inner side. Anterior margin is sharply edged and posterior margin is denticulated.

Material examined.--Four specimen; 2 *d* and 2 "*t*" elements (IGUT-ag2123, 2124).

Occurrence.--Bed LAN-60 in the LAN 1 section.

Remarks.--Only four specimens occur from the studied sections. However, *d* element, having denticulated anterior margin, is significant for identification of this species.

Belodella devonica Stauffer, 1940

Plate 53: 3-5

Belodella devonica (Stauffer, 1940). Klapper and Barrick, 1983, p. 1224, pl. 7, figs. i, j; Anderson, 2003, p. 470, pl. 3, figs. 1-3.

Belodus debonicus Stauffer, 1940, p. 420, pl. 59, figs. 47, 48.

Description.--Element is characterized by its high, slender, and triangular shape in lateral view. Simple cusp is proclined to erect. Posterior margin is finely denticulated at base. Symmetrical to asymmetrical specimens correspond to *a*, *b*, and *c* elements. *C* element is symmetrical unit. Most of them are triangular in cross-section at base, but some are lenticular. Asymmetrical *b* and *a* element twist inwardly and have triangular and lenticular cross-sections at base, respectively.

Material examined.--One hundred and five specimen; 14 *a*, 22 *b*, and 69 *c* elements (IGUT-ag2125 to 2127).

Occurrence.--Beds LAN-64 and 65 in the LAN 1 section.

Belodella resima (Philip, 1965)

Plate 52: 4, 5

Belodus reminus Philip, 1965, p. 98, pl. 8, figs. 15-17, 19.

Belodella devonica (Stauffer, 1940). Mawson, 1987, p. 272, pl. 5, figs. 4, 5, 7; Mawson and Talent, 1989, p. 258, pl. 8, figs. 1, 2; Wilson, 1989, p. 148, pl. 1, figs. 4-7; Mawson and Talent, 1994, p. 58, pl. 4, figs. 5-7.

Belodella resima (Philip, 1965). Mawson, 1987, p. 272, pl. 5, figs. 6, 8. 11, 12; Wilson, 1989, p. 148, pl. 1, figs. 1-3; Mawson and Talent, 1994, p. 66, fig. 15: g; Mawson, Talent, and Furey-Greig, 1995, p. 424, pl. 4, figs. 2-9; Anderson, 2003, p. 470, pl. 1, figs. 1-20, pl. 2, figs. 1-10; Farrell, 2003, p. 121, pl. 1, figs. 14-21; Mawson et al., 2003, pl. 5, figs. 1-6, 10, 11; Farrell, 2004, p. 954, pl. 2, figs. 6-13.

Belodella triangularis (Stauffer, 1940). Mawson, 1987, p. 272, pl. 5, fig. 13; Wilson, 1989, p. 148, pl. 1, figs. 8, 9; Mawson and Talent, 1994, p. 66, fig. 15: n-p.

Description.--Bilaterally symmetrical *c* element occurs from the study section. Element has erect cusp and flattened anterior face with two keeled anterolatearl costae. Cross-section of base is antero-posteriorly elongated triangular. Posterior margin is denticulate at base.

Material examined.--Four specimen; 4 *c* elements (IGUT-ag2109, 2110).

Occurrence.--Beds LAN-56 and 57 in the LAN 1 section.

Genus ***Besselodus*** Aldridge, 1982

Type species.--Besselodus arcticus Aldridge, 1982.

Remarks.--This genus was established by Aldridge (1982) on the basis of fused cluster. He reconstructed a bimembrate apparatus for this genus. Leslie (2000) described three types of elements, containing distacodontiform, acontiodontiform, and oistodontiform elements, as components of apparatus of this genus.

Besselodus semisymmetricus (Hamar, 1966)

Plate 45: 15

Acontiodus semisymmetricus n. sp. Hamar, 1966, p. 51, pl. 7, figs. 5, 6, text-fig. 3, no. 6.

Paltodus semisymmetricus (Hamar, 1966). Dzik, 1976, p. 435, text-fig. 18: b-f.

Paltodus? *semisymmetricus* (Hamar, 1966). Dzik, 1994, p. 76, text-fig. 12: d, pl. 16, figs. 14, 15.

Besselodus semisymmetricus (Hamar, 1966). Leslie, 2000, p. 1126, figs. 3, 15-19; Agematsu, Sashida, Salyapongse, and Sardsud., in press C.

Description.--Element has reclined to recurved cusp and laterally compressed base, which is extended posteriorly. Longitudinal costa is on at least one anterolateral face and more pronounced at point of maximum curvature of unit.

Material examined.--One specimen; 1 "distacodontiform" element (IGUT-ag1153).

Occurrence.--Bed ST-3 in the ST 1 section.

Remarks.--Leslie (2000) did not mention a locational notation of elements. I cannot discuss the apparatus reconstruction of this species with single specimen.

Besselodus variabilis (Bergström, 1962) is closely related to *B. semisymmetricus* and has similar distacodontiform elements (Leslie, 2000). The specimen of this study does not have the most conspicuous character of the former, which is a small knob-like keel at the posterior end of the basal margin.

Genus ***Dapsilodus*** Cooper, 1976

Type species.--Distacodus obliquicostatus Branson and Mehl, 1933.

Remarks.--Apparatus is composed of coniform elements, which are laterally compressed and have triangular base in lateral view. Dzik (1994) illustrated three or four morphotypes in the apparatus of this genus.

Dapsilodus hamari (Igo and Koike, 1967)

Plate 51: 5-11

Acontiodus hamari Igo and Koike, 1967, p. 15, 16, pl. 1, figs. 6-8, 10, 11 (only), text-fig. 6:f.

Description.--A, *b*, *c*, and *e* elements are identified. These elements are slender and laterally compressed units with erect to recurved cusp. Longitudinal, sharp costae are developed on both lateral faces in a, *b*, and *c* element and on one lateral face in *e* element. The costae extend along posterior margin from mid base to tip of cusp. Bilaterally symmetrical *c* element is erect to recurved and has a maximum recurvature at one-third length of element from basal margin. Some specimens has narrowly rounded anterior face. Others have a flattened anterior face, which is edged by two anterolateral keels. Upper margin of base is short and keeled, and meet basal margin at 90 to 110°. Anterior margin downwardly extends and form anterobasal corner with 60 to 80°. Basal margin turns up at a position of one-half length with an angle of 110 to 120°. Outline of basal margin in aboral view is narrowly elliptical, whose anterior end splits in some specimens. Bilaterally subsymmetrical *b* element is similar to *c* element. Erect to reclined cusp outwardly twists. Inner anterolateral costa is slightly shifted posteriorly. Anterobasal corner prominently projects and forms an angle about 60°. Asymmetrical *a* element resembles *b* element. However, *a* element strongly twists and its anterolateral costa on inner side is weakened. *E* element is more stout unit than the other elements. Lateral compression is relatively strong and forms anterior and posterior keels. Cusp is erect. Upper margin of base is short and keeled. Basal margin is slightly convex on outer side and concave on inner side in lateral view. *A*, *b*, and *c* elements form a symmetry transition series.

Material examined.--One hundred and seventy two specimens; 14 *a*, 30 *b*, 58 *c*, 70 *e* elements (IGUT-ag2095 to 2101).

Occurrence.--Beds LAN-49 to 55 in the LAN 1 section.

Remarks.--Igo and Koike (1967) described this species as *Acontiodus* sp. However, above-mentioned characteristics and composition of apparatus suggest that this species belongs to *Dapsilodus*. Igo and Koike (1967) listed *Distacodus* sp. described by Hamar (1964) as a synonym of *Dapsilodus hamari*. *Distacodus* sp. of Hamar (1964) is markablly reclined and has base, whose upper and anterior margins are relatively long and short, respectively. Anterior margin meet basal margin at 90°. Maximum curvature of basal margin in lateral view is a right angles. On the basis of these features, *Distacodus* sp. is distinguished from *D. hamari*. Although *D. hamari* is similar to *Dapsilodus praecipuus* Barrik, 1977, these species differ in following points; element of *D. hamari* has markably short upper margin; basal margin of *a*, *b*, and *c* elements of *D. hamari* is downwardly convex in lateral view, in contrast to *D. praecipuus*, whose basal margin is straight.

Dapsilodus mutatus (Branson and Mehl, 1933)

Plate 47: 5-7, 11

Belodus(?) *mutatus* n. sp. Branson and Mehl, 1933, p. 126, pl. 10, fig. 17.

Dapsilodus mutatus (Branson and Mehl, 1933). Bergström, 1978, pl. 80, figs. 21-23; Orchard, 1980, p. 20, pl. 5, figs. 6, 15, 16, 21; Dzik, 1994, p. 64, pl. 11, figs. 24-26, 31-35; pl. 14, figs. 8, 9, text-fig. 6: d; Ferretti and Barnes, 1997, pl. 3, figs. 15-19; Agematsu, Sashida, Salyapongse, and Sardsud, in press C.

Distacodus procerus n. sp. Ethington, 1959, p. 275, pl. 39, fig. 8.

Acontiodus procerus (Ethington, 1959). Serpagli, 1967, p. 46, 47, pl. 9, figs. 6-11.

Description.--Element is erect to reclined, with maximum curvature at half length of unit. Cusp is slender and twisted. Base is strongly expanded to posterior and triangular in shape in lateral view. Sharp-edged costae are on each posterolateral side, which are most remarkable at point of maximum curvature and disappear before reaching both basal margin and tip of cusp. Anterior and posterior margins are keeled, and form angles of 80 to 90° and 45 to 60° with basal margin, respectively. Oral outline of base is a narrow oval with bluntly edged posterior end, and anterior one-third is almost closed laterally.

Material examined.--Eighty specimens (IGUT-ag1439, 1420, 1454, 1651).

Occurrence.—Beds ST-4 to 10 and 12 to 18 in the ST 1 section and beds LAN-30, 31, 33, 37 to 39, and 70 to 81 in the LAN 1 section.

Remarks.--Specimens recovered in this study are compared with the "hi" element of Dzik (1994). Stratigraphic range of this species covers slightly higher beds than that of *Scabbardella altipes* in the LAN 1 section.

Dapsilodus obliquicostatus (Branson and Mehl, 1933)

Plate 52: 6-9

Acodus mutatus (Branson and Mehl, 1933). Serpagli, 1967, p. 856.

Acontiodus procerus (Ethington, 1959). Serpagli, 1967, p. 856.

Dapsilodus obliquicostatus (Branson and Mehl, 1933). Cooper, 1976, p. 212, pl. 2, figs. 10-13, 18-20; Uyeno, 1990, p. 98, pl. 2m figs. 11-15; Kozur, 1998, pl. 1, fig. 6.

Distacodus obliquicostatus Branson and Mehl, 1933, p. 41, pl. 3, fig. 2; Nicoll and Rexroad, 1968; p. 31, pl. 7, figs. 1-4; Aldridge, 1972, p. 171, pl. 8, fig. 4.

Distacodus procerus Ethington, 1959. Ethington and Furnish, 1962, p. 1265.

Description.--Elements is characterized by ornamented anterior margin with short, oblique striations, and by large, triangular base in lateral view. Cusp is slender and sharply reclined. Specimens are divided into *a/b* and *c* elements. *C* element is bilaterally symmetrical and anterior margin is generally compressed. Some specimens have narrowly flattened or concave anterior face, which is edged by two anterolateral keels. Posterior margin is sharply edged. Upper margin of base is laterally compressed. Asymmetrical *a/b* element possesses sharp posterolateral costa on inner face. Anterior margin is laterally compressed and inwardly bent.

Material examined.--Forty five specimens; 14 *a/b* and 31 *c* elements (IGUT-ag2111 to 2114).

Occurrence.--Beds LAN-51 to 55 in the LAN 1 section.

Remarks.--According to Serpagli (1974) and Barrick (1977), obliquely striated anterior margin, elongate base, and deep basal cavity are the characteristics, which distinguish *D. obliqicostatus* from other species of this genus. The specimens from the study section show these characteristics. Anterior margin of *a/b* and *c* elements from the study sections is generally edged, and a few specimens have anterior margin, which splits into two anterolateral keels. Elements of *Daosilodus sparsus* and *Dapsilodus hamari*, which co-occur with *D. obliquicostatus* from the study sections, predominantly have anterior margin with two keels.

Dapsilodus praecipuus Barrick, 1977

Plate 51: 12

Dapsilodus praecipuus Barrick, 1977, p. 52, pl. 2, figs. 1-5.

Description.--Elements is bilaterally symmetrical and has erect to recurved cusp. Anterior margin typically splits two keels at base. Posterior margin is laterally compressed. Two sharp-edged costae are situated on middle to posterior part of each lateral face. Base is expanded antero-posteriorly. Basal margin is straight and forms angles of 45 to 60° with anterior and posterior margin.

Material examined.--Five specimens; 5 *c* elements (IGUT-ag2102).

Occurrence.—Beds LAN-49, 50, and 53 in the LAN 1 section.

Remarks.--The specimens conform with description of Barrick (1977). They are bilaterally symmetrical and assigned to *c* element in apparatus of this species.

Dapsilodus sparsus Barrick, 1977

Plate 52: 1-3

Dapsilodus sparsus Barrick, 1977, p. 52, 53, pl. 2, figs. 7-9, 11.

Description.--Elements form a symmetry transition series. Cusp is erect to recurved and laterally compressed. Each lateral face bears sharp-edged costae from above basal margin to tip of cusp along posterior margin. Anterior margin is keeled. Basal margin is downwardly convex in lateral view. *C* element is bilaterally symmetrical and erect. Asymmetrical *a/b* element is erect to recurved and inwardly twists. Posterolateral costa on one side is rather shallow.

Material examined.--Ten specimens; 8 *a/b* and 2 *c* elements (IGUT-ag2106-2108).

Occurrence.--Beds LAN-54 and 55 in the LAN 1 section.

Remarks.--Element of *D. pracipuus* has base with sharp corners at anterior and posterior ends of straight basal margin. Anterior margin of this species typically splits. On the other hand, antero- and posterobasal corners of elements of *D. sparsus* are rounded. Basal margin gently curves and anterior margin is laterally compressed. These characteristics distinguish the two species. *D. sparsus* is discriminated from *D. hamari* by having strongly projected posterobasal corner.

Genus ***Hamarodus*** Viira, 1974

Type species.--Distomodus europaeus Serpagli, 1967.

Remarks.--Dzik (1994) mentioned that the genus has seven morphotypes in the apparatus, consisting of *a*, *b*, *c*, *d*, *e*, *f*, and *g* elements.

Hamarodus europaeus (Serpagli, 1967)

Plate 48: 1-16

Neoprioniodus brevirameus n. sp. Walliser, 1964, p. 47, pl. 4, fig. 5; pl. 29. figs. 5-10.

New genus and new species Hamar, 1966, p. 77, pl. 3, figs. 8-10, text-fig. 5: no. 5.

Distomodus europaeus n. sp. Serpagli, 1967, p. 64, pl. 14, figs. 1-6.

Hamarodus europeaus (Serpagli, 1967). Dzik, 1976, p. 435, text-fig. 36: a-g; Dzik, 1978, text-fig. 2; Orchard, 1980, p. 21, pl. 4, figs. 22, 25, 29-31; Ferretti and Barnes, 1997, p. 22, 23, pl. 3, figs. 1-14; Ferretti and Serpagli, 1999, p. 226, 228, pl. 2, figs. 1-14; Sweet, 2000, fig. 9-1, 9-2; Agematsu, Sashida, Salyapongse, and Sardsud, in press C.

Hamarodus brevirameus (Walliser, 1964). Dzik, 1994, p. 111, 112, pl. 24, figs. 14-19, text-fig. 31: a.

Description.--Six types of elements are recognized in the collection of this study. *F* element is proclined triangular unit in lateral view with flared base and cusp tapering toward tip. Basal cavity is deep and conical with tip located at one-half to two-thirds length of unit from basal margin. Anterior and posterior margins are sharply edged and more keel-like at the lower part of base. These keels, bearing several short denticles basally, project beneath main part of basal margin. Outline of aboral margin is expanded laterally and has sharply elongated anterior and posterior ends. Anterior edge is longer than posterior one and deflected to inner side. Inner lateral margin is more broadly convex than outer. One specimen has a longitudinal median keel-like ridge on outer-lateral surface.

Elements forming a symmetry-transition series have erect to reclined cusp, slender base, and denticulate posterior process. Posterior process is strongly laterally compressed and has several small denticles separated by denticles that are more than twice as large. *C* element is a symmetrical unit. Base bears narrow costae on both anterolateral faces with rather concave anterior surface. *B* element has asymmetrical transverse section with narrow ridge on anterolateral margin. One lateral face is broadly convex and other face is more planar in oral view of base. *A* element has cusp with circular cross section and a small denticle along anterior edge of base. Base of *d* element bears ridges with small denticle on each side. It has anteroposteriorly symmetrical basal margin in oral view.

E element is a relatively long, slender unit. Cusp curves slightly inward and is lenticular in transverse section. Base has sharp-pointed anterior end and elongate upper margin, which has a similar length to posterior margin of cusp. Basal cavity is narrow in oral view.

Material examined.--One hundred and twenty one specimens; 11 *a*, 23 *b*, 11 *c*, 5 *d*, 38 *e*, and 43 *f* elements (IGUT-ag1461, 1462, 1468-1470, 1513, 1560, 1564, 1623, 1654, 1659, 1690, 1691, 1718, 17191775,).

Occurrence.--Beds ST-6 to 12, 17, and 18 in the ST 1 section and beds LAN-35 to 39, 79, and 80 in the LAN 1 section.

Remarks.--Orchard (1980) proposed three morphotypes of elements forming a symmetry transition series, four are identified here. Dzik (1994) recognized two types of elements in conical specimens and described *f* and *g* elements. It is difficult to discriminate these elements. Dzik (1994) suggested the species name, *Hamarodus brevirameus*. Ferretti and Serpagli (1999) discussed this problem and concluded that Dzik's (1994) nomenclature was insufficient because it stood on incomplete collections. I follow the concept of Ferretti and Serpagli (1999) and use the name *Hamarodus europaeus*.

Genus ***Pygodus*** Lamont and Lindström, 1957

Type species.-- *Pygodus anserinus* Lamont and Lindström, 1957.

Remarks.--The multielement apparatus of *Pygodus* consists of ramiform elements forming a symmetry transition series (*a*, *b*, and *c*) and haddingodontiform (*g*) and pygodontifom (*f*) elements (Bergström, 1971, 1983; McCracken, 1991). Zhang (1998) discussed the evolution of *Pygodus* based on the most characteristic *f* element.

Pygodus anserinus Lamont and Lindström, 1957

Plate 45: 1-4

Pygodus anserinus Lamont and Lindström, 1957. Sweet and Bergström, 1962; Hamar, 1966, pl. 7, fig. 1; Bergström, 1971, p. 149, pl. 2, figs. 20, 21; Dzik, 1976, p. 440, text-fig. 29: f; Bergström, 1978, pl. 79, figs. 1, 2; Harris, Bergström, Ethington, and Ross, 1979, pl. 3, figs. 16, 17; pl. 4, fig. 17; Dzik, 1994, p. 105, 106, pl. 17, figs. 7, 8, text-figs. 26, 27; Zhang, 1998, pl. 3, figs. 1-8; Wang and Qi, 2001, pl. 2, figs. 19, 21, 25, 26; Agematsu, Sashida, Salyapongse, and Sardsud, in press C.

Description.--*F* element has triangular outline and flat to arched platform with four denticle rows on platform. These ridges are straight or smoothly concave to inner side. The three rows, except second row from inner side, which is shorter than others, diverge from cusp.

G element has denticulated posterior process that is moderately high and tapers in height toward posterior. Main cusp curved strongly and at least 12 denticles on posterior bar incline posteriorly.

Material examined.--Four elements; 3 *f* and 1 *g* elements (IGUT-ag1004, 1005, 1068, 1069).

Occurrence.--Beds ST-1 and 2 in the ST 1 section.

Remarks.--Zhang (1998) discussed the morphological variation of *Pygodus* lineage through time. The number of denticle rows and arrangement of our specimens define them as *P. anserinus*, the youngest descendant.

Genus ***Walliserodus*** Serpagli, 1974

Type species.--*Paltodus debolti* Rexroad, 1967

Walliserodus costatus Dzik, 1976

Plate 41: 7, 8

Walliserodus costatus Dzik, 1976, p. 421, pl. 41, fig. 2, text-fig. 14: m, n; Dzik, 1978, pl. 15, fig. 7; Dzik, 1994, p. 56, pl. 12, figs. 1-6, test-fig. 2: a; Albanesi, 1998b, p. 113, 114, pl. 14, figs. 15-19, text-fig. 7.

Walliserodus cf. *ethingtoni* Fåhræus, 1966. Löfgren, 1978, p. 113, pl. 4, fig. 13, 14.

Materials examined.--Two specimens; 1 *a/b* element 1 *e* element (IGUT-ag1799, 1800).

Occurrence.--Bed TW2 in the TUW 1 section.

Remarks.--Dzik (1994) described three species belonging to this genus, and distinguished elements in their apparatuses into six forms. Symmetry *a/b* element and acostate e element are recognized in our collection. *A/b* element with three costae on each lateral faces is antero-posteriorly symmetrical unit. Base is elongated. Anterior margin is gently rounded and posterior margin is weekly keeled through unit. *E* element is laterally compressed and has rounded lateral faces. Anterior and posterior margins are strongly keeled at base. Basal margin is oval shape with narrow anterior edge in aboral view.

Class **Conodonti** Sweet, 1988

Genus ***Acanthodus*** Furnish, 1938

Type species.--Acanthodus unicinatus Furnish, 1938

Acanthodus lineatus (Furnish, 1938)

Plate 38: 16

Drepanodus lineatus Furnish, 1938, p. 328, pl. 41, figs. 33, 34, text-fig. 1h.

Acanthodus lineatus (Furnish, 1938). Ethington and Clark, 1982, p. 17, pl. 1, fig. 7; Repetski, 1982, p. 10, pl. 1, figs. 1, 3; Ji and Barnes, 1994, p. 24, 25, pl. 1, figs. 1-8, text-fig. 22: a.

Description.--Sspecimen has slender cusp and expanded base. One lateral face has a sharp costa from above basal margin to tip of cusp. This element is identified with "asymmetrical element", described by Furnish (1938).

Materials examined.--One specimen; 1 *a* element (IGUT-ag2001).

Occurrence.--Bed TAR-17 in the TAR 2 section.

Remarks.--Characteristics of the element conform with the description of Ji and Barnes (1994).

Genus ***Acodus*** Pander, 1856

Type species.--Acodus erectus Pander, 1856

Remarks.--I follow Zhen et al. (2003b), regarding *Tropodus* as a junior synonym of *Acodus*. According to them, this genus has apparatus consisting *a*, *b*, *c*, *d*, *f*, and *g* elements.

Acodus comptus (Branson and Mehl, 1933)

Plate 38: 10, 11

Acodus comptus (Branson and Mehl, 1933). Ji and Barnes, 1994, p. 26, pl. 2, figs. 1-21, text-fig. 23: a.

Paltodus comptus Branson and Mehl, 1933, p. 61, pl. 4, fig. 9; Zhen, Percival, and Webby, 2003b, p.50, 51, pl 1, figs. 1-19.

Scolopodus pseudoquadratus Branson and Mehl, 1933, p. 63, pl. 4, fig. 19.

Tropodus comptus (Branson and Mehl, 1933). Kennedy, 1980, p. 65, 66, pl. 2, figs. 20-27; Stouge and Bagnoli, 1988, p. 141, 142, pl. 16, figs. 1-8 (only); Albanesi, 1998b, p. 151, pl. 13, figs. 19-22; Johnston and Barnes, 2000, p. 47, pl. 11, fig. 22, pl. 15, figs. 22, 23, pl 16, figs. 26-29.

Tropodus comptus australis (Serpagli, 1974). Löfgren, 1993, fig.9: o, s, t.

Walliserodus comptus Ethington and Clark, 1982, p. 114, pl. 13, figs. 6, 7, 11-13, text-fig. 34.

Walliserodus australis Serpagli, 1974, p. 89-91, pl .19, figs. 6, 7, pl. 29, fig. 9, 11-12.

Material examined s.--Two specimen; 2 *d* element (IGUT-ag1995, 1996).

Occurrence.--Bed TAR-42 in the TAR 2 section.

Remarks.--Element has edge-like anterolateral and posterolateral costae on each lateral face and keeled posterior margin. This element is idendified a form species *Scolopodus qseudoquadratus* Branson and Mehl, 1933. Kennedy (1980) described this form species and *Paltodus comptus* Branson and Mehl, 1933 as components of multielement species *Tropodus comptus* (Branson and Mehl, 1933). I follow Zhen et al. (2003b) and assign the specimen of this study to *d* element of *Acodus comptus*.

Acodus* sp. cf. *A. deltatus (Lindström, 1955)

Plate 43: 7-9

Materials examined.--Eight specimens; 1 *a*, 4 *b*, 2 *c*, and 1 *d* elements (IGUT-ag2039 to 2041).

Occurrence.--Beds LAN-76 and 77 in the LAN 2 section.

Remarks.--Ethington and Clark (1982) described six types of elements as apparatus of this species containing drepanodiform, prioniodiform, gothodiform, distacodiform, trichonodelliform, and oistodiform elements. Collection of this study yields *a*, *b*, *c*, and *d* elements. However, *b* and *c* elements differ in shape from those of *A. deltatus* described by Ethington and Clark (1982). The *b* and *c* elements of this study have elongate and slender base with developed upper blade. These characteristics are similar to *b* and *c* elements of *Acodus deltatus deltatus* Lindström, 1955 and

Acodus deltatus liongibasis McTavish, 1973. However, it is difficult to discuss the taxonomy of the element due to few specimens.

Acodus sevierensis Miller, 1969

Plate 1: 11-13

Acodus sevierensis Miller, 1969, p. 418, pl. 63, figs. 21-24, 32 (only), text-fig. 3: h.

Materials examined.--Twenty one specimens; 1 *a* element, 3 *b* elements, and 17 *c* elements (IGUT-ag1943 to 1945).

Occurrence.--Bed TAR-3, 4, 6-8, 11, and 14 in the TAR 1 section.

Remarks.--Elements coincide with description of Miller (1969). On the basis of number and position of costae, the elements are divided into *a*, *b*, and *c* elements, which form a symmetry transition series

***Acodus* sp. A**

Plate 43: 1-4

Materials examined.--Nine specimens; 2 *b*, 3 *c*, 1 *e*, and 3 *f* element (IGUT-ag1801, 1802, 1804, 1805).

Occurrence.--Bed TUW-10 in the TUW 2 section and beds LAN-76 and 77 in the LAN 2 section.

Remarks.--*C*, *e* and *f* elements are similar to those of *Acodus comptus* (Branson and Mehl, 1933) described by Zhen et al. (2003a). However, *b* element of this pecies differs from that of *Acodus comptus* in the asymmetrical unit, which has three blade-like costae and a keeled posterior margin. Basal margin is trapezoid in aboral view.

Genus ***Amorphognathus*** Branson and Mehl, 1933

Type species.--*Amorphognathus ordovicica* Branson and Mehl, 1933.

Remarks.--Branson and Mehl (1933) proposed the name of *Amorphognathus* to branched asymmetrical denticulate pectiniform elements. Several studies have revealed that the genus has a septimembrate apparatus (e.g., Orchard, 1980). Dzik (1994) proposed that "amorphognathus" (*g*) and "holodontiform" (*e*) elements were most useful for identification of species belonging to the genus, which have seven morphotypes.

Amorphognathus sp. A

Plate 49: 3, 6

Description.--*F* and *g* elements occur from the study sections. *G* element has roughly crescent-shaped base in lateral view and stout cusp. Row of fused denticles is developed on anterior process, which is longer than posterior one and forms lanceolate plate. Small adenticulate lateral process is on outer side. Anterolateral processes deflected orally. *F* element is asymmetrical denticulated plate with rays extending both lateral sides within common basal plane that is slightly arched. All processes are more or less lanceolate-shape in oral view, with conspicuous longitudinal median crest on oral surface that consists of fused denticles. Inner ray has two small branches of unequal size. Outer ray is broken. Anterior process curves gently to outer side and tapers to anterior end in oral view from lateral lobes; outer lobe is larger than inner.

Material examined.--Ten specimens; 4 *f* and 6 *g* element (IGUT-ag01446, 01447).

Occurrence.--Bed ST-6 in the ST 1 section and beds LAN-39 and 79 in the LAN 1 section.

Remarks.--Identification of apparatus among several *Amorphognathus* species is mainly based on *e* element (e.g., Dzik, 1994). It is impossible to give a species name to the specimens of this study, because of the absence of *e* elements.

Genus ***Aurilobodus*** Xiang and Zhang, 1983 (in An et al., 1983)

Type species.-- *Tricladiodus? aurilobus* Lee, 1975a.

Aurilobodus leptosomatus An, 1983 (in An et al., 1983)

Plate 40: 11, 12

Aurilobodus leptosomatus An, 1983 (An et al., 1983), p. 72, 73, pl. 21, figs. 14-17, pl. 22, fig. 1; Agematsu, Sashida, Salyapongse, and Sardsud, in press A.

Aurilobodus? leptosomatus An, 1983. Stait and Druce, 1993, p. 302, fig. 17: a-c.

Juanognathus leptosomatus (An, 1983). Watson, 1988, p. 116, pl. 1, figs. 1-3, 6.

Description.--Symmetrical *s'* and asymmetrical *t* elements are identified. *T* element is antero-posteriorly compressed and generally has flattned anterior face and broadly concave posterior face. Thin, blade-like lateral costae are developed on each side. These costae continue to adenticulated lateral processes, which downwardly extend. One lateral process has straight magin. The other is wider and longer and its margin arches. Small and shallow basal cavity is located below cusp and posteriorly expanded. *S'* element resembles *t* element. Thin lateral costae widely extend and inwardly bend at base.

Material examined.--Three specimens; 1 *t* and 2 *s'* elements (IGUT-ag2029, 2030).

Occurrence.--Bed TPP-15 in the TPP section, bed LAN-76 in the LAN 2section, and bed LAN-24 in the LAN 1 section.

Remarks.--Watson (1988) recognized asymmertical *t* and *t'* and symmetrical *s* and *s'* elements as apparatus of this species. Elements of the study sections coincide with his *t* and *s'* elements of Watson (1988).

Aurilobodus* sp. cf. *A. leptosomatus An, 1983 (in An et al., 1983)

Plate 40: 10

Material examined.--One specimens; 1 *t* elements (IGUT-ag2028).

Occurrence.--Bed TPP-13 in the TPP section.

Remarks.--Element is laterally compressed and asymmetrical. Thin lateral costae has straight margins and asymmerical length. Although this specimen is similar to *t* element of *Aurilobodus leptosomatus*, it is difficult to discuss the taxonomy due to its poor preservation.

Genus ***Baltoniodus*** Lindström, 1971

Type species.--*Prioniodus navis* Lindström, 1955.

Remarks.--Dzik (1976) and Löfgren (1978) found that *Baltoniodus* was a subgenus of *Prioniodus*, but Lindström et al. (1974) argued for the rank of genus for *Baltoniodus*. Some authors (e.g., Stouge, 1984; Dzik, 1994) agree with the opinion of Lindström et al. (1974). *Baltoniodus* has been reported to have either a seximembrate apparatus (Bergström, 1971; Lindström, 1971) or a septimembrate apparatus (Sweet, 1988; Dzik, 1994).

Baltoniodus* sp. cf. *B. variabilis (Bergström, 1962)

Plate 46: 1-17

Baltoniodus sp. cf. *B. variabilis* (Bergström, 1962). Agematsu, Sashida, Salyapongse, and Sardsud, in press C.

Description.--*F* element is pastinate element with denticulate anterior process directed downward at angle of about 45° from the horizontal plane formed by base of expanded, denticulate, posterior process. Basal margin of posterior process expands to both outer and inner sides and forms asymmetrical platform. Inner platform from cusp to two-thirds length of posterior process in mature specimens extends laterally forming semicircle. Outer platform is narrower than inner side. Height of denticles on posterior process is low at junction with cusp and posterior end, and relatively high at middle of process. Outer lateral process extends downward from erect cusp.

G element is pastinate element with erect to proclined cusp and denticulate anterior and posterior processes. Margin of posterior process is slightly expanded to inner side. Anterior process, which is longer than posterior process and robust in mature specimens, is directed downward at angle of 70-90° from horizontal plane passing along base of posterior process. Lateral process is directed downward.

E element is compressed laterally. Inner lateral face of base is concave and posterobasal corner is deflected to outer side. Elongated and distally tapered anterobasal corner is denticulate on anterior margin of most specimens.

C element has one posterior and two lateral denticulate processes. Lateral processes are directed downward. *A/b* element is bipennate element with proclined cusp and adenticulate slender anterior process. Posterior process has several small, laterally compressed denticles separated by laterally compressed denticules that are more than twice as large. *D* element is asymmetrical quadriramate element with one anterior process, two lateral processes, and one posterior process, all of them denticulate. Denticles on posterior bar are rhythmic similar to those on posterior process of ligonodiniform element. Lateral processes are directed downward.

Material examined.--Seven hundred and eleven specimens; 107 *a/b*, 42 *c*, 145 *d*, 56 *e*, 173 *f*, and 188 *g* elements (IGUT-ag1009, 1018, 1037, 1080, 1133, 1163, 1168, 1172, 1243, 1262, 1306, 1332, 1341, 1362, 1365, 1372).

Occurrence.--Beds ST-2 to 4 in the ST 1 section and beds LAN-27 to 31 in the LAN 1 section.

Remarks.--Bergström (1978) mentioned that an apparatus of *B. variabilis* (=*Prioniodus variabilis*) is similar to those of *B. prevariabilis* (=*P. prevariabilis*) and *B. alobatus* (=*P. alobatus*) except an amorphognathiform element. This element of *B. variabilis* has processes with more conspicuous ledges than that of *B. prevariabilis*. A posterior process of this element of *B. variabilis* has a lower rim than that of *B. alobatus*, and shows a triangular lateral expansion of its inner side. However, Dzik (1994) noted that characteristics distinguishing these three species are obscure, because their platform-like posterior processes exhibit a high variation in their shapes, and a triangular posterior process, which is an identifiable feature of *B. variabilis*, is not shown in its juvenile. The amorphognathiform specimens of this study have thickly ledged processes, which are similar to those of *B. variabilis*, and have a platform with low to high rims in their posterior processes. Although no specimen bears a laterally expanded and triangular posterior process, our specimens are most closely related to *B. variabilis*. A huge collection is necessary for more reliable identification.

Genus ***Bergstroemognathus*** Serpagli, 1974

Type species.--Oistodus extensus Graves and Ellison, 1941

Remarks.--Zhen et al (2001) described three species of this genus and discussed its apparatus. According to them, components of apparatus of this genus are angulate *f* and *g* elements, makellate *e* element, palmate-alate *c* element, and digyrate or bipennate *a*, *b*, and *d* elements.

***Bergstroemognathus* sp. A**

Plate 40: 9

Description.--Bilaterally symmetrical specimen is palmate-alate *c* element and antero-posteriorly compressed. Cusp is located in the center of element, which has denticulated lateral processes. Anterior face is flattened to gently convex and posterior face is broadly concave. Lateral processes bear nine denticles, which are basally confluent and apically discrete. Basal cavity is small and shallow, and posteriorly projects. The cavity laterally continues to basal furrows under lateral processes. Posterior face is rimmed with lateral ridge along basal margin.

Material examined.--Four specimens; 4 *c* elements (IGUT-ag2027).

Occurrence.--Bed LAN-23 in the LAN 1 section and bed LAN-70 in the LAN 2 section.

Remarks.--Element is slightly simiar to that of *Bergstroemognathus extensus* (Graves and Ellison, 1941). However, width, height, and direction of denticulation on lateral processes suggest that the specimens and elements of *B. extensus* are distinguished.

***Bergstroemognathus* sp. B**

Plate 40: 8

Material examined.--Two specimens; 2 *c* elements (IGUT-ag2026).

Occurrence.--Bed TPP-15 in the TPP section.

Remarks.--Bilaterally symmetrical element is antero-posteriorly compressed with flattened to gently convex anterior face and concave. posterior face. One lateral process bears denticles, which are basally confluent and apically discrete. The other process is broken. Basal cavity is small and shallow, and expanded posteriorly. Height and shape of denticles and shape of basal cavity differ from those of *Bergstroemognathus* sp. A.

Genus ***Colaptoconus*** (Kennedy, 1980)

Type species.--Scolopodus quadraplicatus Branson and Mehl, 1933.

Remarks.--Diagnosis of this genus is revised by Ji and Barnes (1994). Apparatus of this genus generally consists of four or five shapes of elements. *A*, *b*, *c*, *e*, and *f* elements are multicostate scolopodiform, tricostate scolopodiform, symmetrical staufferiform, compressed drepanodiform, and ulrichodiniform elements, respectively (Ji and Barnes, 1994).

Colaptoconus bolites (Repetski, 1982)

Plate 36: 1-6, 8

Scolopodus bolites Repetski, 1982, p. 46-47, pl. 21, fig. 9-11.

Glyptoconus bolites (Repetski, 1982). Ji and Barnes, 1994, p. 36, 37, pl. 8, figs. 8-13, text-fig. 25: a.

Description.--Elements are symmetrical to asymmertical coniform and characterized by having costae and deep grooves. They are distinguished into *a*, *c*, and *e* elements. *A* element is subsymmetrical and has proclined to erect cusp with maximum curvature at one-fourth length of element from basal margin. Cusp gradually tapers distally and slightly twists. Base is expanded antero-posteriorly. Anterior face is rounded and smooth. Posterior face is flattened except for well-developed posterior carina. Two lateral sides are keeled as knife-edged lateral costae. Posterior carina commonly without median groove. Base is oval in cross-section. *C* element is proclined to erect and similar to *a* element. However, this element is symmetrical. *E* element is laterally compressed and asymmetrical. Cusp is erect and twists. Anterior face is broadly rounded. Flattened posteiror face has weak carina without median groove. Knife-edged lateral costae begin just above basal margin and continue to tip of cusp. Base is expanded posteriorly and basal margin is oval in aboral view.

Material examined.--Twenty five specimens; 9*a*, 8*c*, and 8*e* elements (IGUT-ag1957 to 1963).

Occurrence.--Beds 16, 17, 20, 21, 23, 27, 28, 32, 33, 36, 38, and 39 in the TAR 2 section.

Remarks.--Ji and Barnes (1994) recognized three types of elements, which constitute apparatus of this species. The specimens of this study conform with description of these elements.

Colaptoconus floweri (Repetski, 1982)

Plate 36: 7, 9-12

Scolopodus floweri Repetski, 1982, p. 47, 48, pl. 24, figs. 7, 9, pl. 25, figs. 1, 4.

Glyptoconus floweri (Repetski, 1982). Ji and Barnes, 1994, p. 39, pl. 8, figs. 14-26, text-fig. 25: b.

Description.--Element is slender and costate having long cusp and small base. Four types elements, *a*, *b*, *c*, and *e*, are recognized in the collection of this study. Erect and symmetrical *a* element has two lateral costae and two anterolateral costae. These costae are sharply edged and extend from just above basal cavity to tip of cusp. Anterior face is broadly convex. Posterior face is narrowly rounded distally, and flattened at point of maximum curvature of element. Base is flared posteriorly. Basal margin is elliptical in aboral view. *B* element is asymmeretical unit and has erect to reclined cusp and short base. One anterolateral costa and two posterolateral costae begin from above basal margin to tip of cusp. Base is antero-posteriorly compressed. Basal margin is elliptical in aboral view. *C* element is symmertical, erect, and laterally compressed form. Anterior face is edged by two anterolateral costae. Posterior face has sharp posterior carina. Outline of basal margin is triangular in aboral view. *E* element is strongly compressed anterior - postseriorly and twists. Cusp has broadly rounded anterior face and convex posterior face. Lateral margins are keeled. Base is expanded posteriorly.

Material examined.--Thirty two specimens; 18 *a*, 11 *b*, 2 *c*, and 1 *e* elements (IGUT-ag1964 to 1968).

Occurrence.--Beds 16-18, 20, 22, 42, 44, and 46 in the TAR 2 section.

Remarks.--The specimens coincide with four types of element, which are described by Ji and Barnes (1994).

Colaptoconus quadraplicatus (Branson and Mehl, 1933)

Plate 35: 12, 14, 15

Colaptoconus quadraplicatus (Branson and Mehl, 1933). Albanesi, 1998b, p. 122, pl. 2, figs. 18-25; Pyle, Barnes, and Ji, 2003, figs. 5: 16-18.

Drepanodus parallelus Branson and Mehl, 1933, p. 59, pl. 4, fig. 17; Lee, 1975b, p. 85, 96, pl. 1, fig. 16, text-fig. 3m; Repetski, 1982, p. 21, pl. 6, figs. 9, 10.

Drepanodus subarcuatus Furnish, 1938, p. 328, pl. 41, figs. 25, 32; Ethington and Clark, 1964, p. 689, pl. 113, fig. 20.

Glyptoconus quadraplicatus (Branson and Mehl, 1933). Kennedy, 1980, p. 61-63, pl. 1, figs. 39-41, 45;

Ji and Barnes, 1994, p. 39, pl. 8, figs. 14-26, text-fig. 25: b; Seo, Lee, and Ethington, 1994, figs. 8-11, 11-8--11.

Scolopodus quadraplicatus Branson and Mehl, 1933, p. 63, pl. 4, figs. 14, 15; Furnish, 1938, p. 332, pl. 41, figs. 1-12, text-fig. 1: j; Ethington and Clark, 1971, p. 73, pl. 2, fig. 5; Repetski, 1982, p. 50, pl. 23, figs, 4, 5.

Material examined.--Two specimens; 2 *a* elements (IGUT-ag1954-1956).

Occurrence.--Bed TAR 41 in the TAR 2 section.

Remarks.--Ji and Barnes (1994) described *a*, *b*, *c*, *e*, and *f* elements and revised definition of apparatus of this species. Only two specimens occur from the study section, but they conform with description of Ji and Barnes (1994).

Genus ***Cooperignathus*** Zhen, Percival, and Webby, 2003b

Type species.--Protoprioniodus nyinti Cooper, 1981

Remarks.--Conodonts belonging to this genus, which is established by Zhen et al. (2003b), have seximembrate apparatus composed of ramiform and pectiniform elements having adenticulate processes. All elements have a ledge-like costa above the basal margin. Two species, *C. aranda* and *C. nyinti* are included in this genus, to date.

Cooperignathus aranda (Cooper, 1981)

Plate 42: 12-15

New genus A Sweet et al., 1971. Repetski, 1982, p. 56, pl. 27, figs. 1-6.

Cooperignathus aranda (Cooper, 1981). Zhen, Percival, and Webby, 2003b, p. 188, 190, fig. 12: a-p.

Oelandodus costatus van Wamel, 1974. An, Du, and Gao, 1985, pl. 6, fig. 20 (only).

Protoprioniodus aranda Cooper, 1981, p. 175, 176, pl. 30, figs. 1, 6, 7, 10, 12; Ethington and Clark, 1982, p. 86. 87, pl. 9, figs. 27-29 (only); Fåhræus and Roy, 1993, p. 30, 31, text-fig. 5: 21-23; Pohler, 1994, pl. 6, figs. 10-12; Johnston and Barnes, 2000, p. 42, pl. 6, figs. 26, 30 (only); Norford, Jackson and Nowlan, 2002, pl. 3, figs. 4-6; Pyle, Barnes and Ji, 2003, figs. 8-18, 8-19.

Protoprioniodus nyinti Cooper, 1981. Stait and Druce, 1993, p. 317, pl. 19, fig. m (only); Pyle, Barnes and Ji, 2003, figs. 8-22, 8-23 (only).

Protoperioniodus simplicissimus McTavish, 1973. Albanesi, 1998b, p. 170, pl. 10, fig. 22 (only).

Material examined.--Ten specimens; 2 *a* elements, 3 *b* elements, 3 *c* elements, 2 *e* elements (IGUT-ag1815, 1817, 1827, 1829).

Occurrence.--Bed TUW-15 in the TUW 2 section and beds LAN-77 and 78 in the LAN 2 section.

Remarks.--*A*, *b*, *c*, and *e* elements are recognized in the collection of this study. Zhen et al. (2003b) describes *a*, *b*, *c*, *e*, *f*, and *g* elements in a seximembrate apparatus of this species. *F* and *g* elements are also reported from New Mexico (Repetski, 1982). However, *f* and *g* elements are not recognized in the Cooper's (1981) collection from the Horn Valley Siltstone, which yields more than 200 elements of this species. Discussion of the apparatus of this species requires more specimens of f and g elements. Although Johnston and Barnes (2000) relegates the elements of *Protoprioniodus yapu* to a part of an apparatus of *P. aranda* (= *Cooperignathus aranda*), we follow the concept of Zhen et al. (2003b) that *P. yapu* is one of the species of the genus *Protoprioniodus* McTavish, 1973.

The specimen of *Oelandodus costatus* in An et al. (1985; pl. 6, fig. 20) has a stout cusp with a conspicuous costa on the posterior face and a ledged-like costa, which is parallel to a basal margin, on the inner and outer lateral processes. On the basis of these characteristics, the specimen of An et al. (1985) is identified to e element of *C. aranda*.

Cooperignathus nyinti (Cooper, 1981)

Plate 42: 4, 7-11

Cooperignathus nyinti (Cooper, 1981). Zhen, Percival, and Webby, 2003b, p. 184-188, figs. 10: a-n, 11: a-o.

Protoprioniodus nyinti Cooper, 1981, p. 176, 178, pl. 29, figs. 1-8, 11, 12; Pyle, Barnes and Ji, 2003, figs. 8-20, 8-21 (only).

Protoprioniodus aranda Cooper, 1981. Ethington and Clark, 1982, p. 86. 87, pl. 9, figs. 24-26, 30 (only); Johnston and Barnes, 2000, p. 42, pl. 6, figs. 23, 24 (only).

Material examined.--Twenty six specimens; 4 *b* elements, 2 *c* elements, 9 *e* elements, and 11 *f* elements (IGUT-ag1818, 1819, 1825, 1830, 1833, 1836).

Occurrence.--Bed TW15 in the TUW 2 section.

Remarks.--*B*, *c*, *e*, and *f* elements occur from the study section. Cooper (1981) and Zhen et al. (2003b) recognized five and six types of elements in apparatus of this species, respectively. *B* and *c* elements show a symmetry transition series. *E* element is able to be distinguished from that of *Cooperignathus* *aranda* by wavy basal margin in anterior and posterior view and an acute angle, about 30°, between costa on posterior face of cusp and ledged-like horizontal costa on inner and outer lateral processes. *F* element is a crescent unit with a ledged-like costa above basal margin. On the basis of a size of outer lateral process, Zhen et al. (2003b) distinguished *g* element from *f* element. However, *f* element has gradual variation in conspicuousness of their outer lateral processes. Therefore, it is difficult to separate *f* and *g* elements in the collection of this study.

Genus ***Cornuodus*** Fåhræus, 1966

Type species.--*Cornuodus erectus* Fåhræus, 1966.

Cornuodus longibasis (Lindström, 1955)

Plate 35: 13, 16, 17

Drepanodus longibasis Lindström, 1955. p. 564, pl. 3, fig. 31.

Cornuodus erectus n. sp. Fahræus, 1966, p. 20, pl. II, fig. 8, text-fig. 2: b.

"Cornuodus" longibasis (Lindström, 1955). Serpagli, 1974, p. 43, pl. 7, fig. 2, pl. 20, fig. 12.

Cornuodus longibasis (Lindström, 1955). Landing, 1976, p. 631, pl. 1, figs. 12, 13, 15; Stouge, 1984, p. 62, pl. 8, figs. 1-8; Stouge and Bagnoli, 1988, p. 114, pl. 1, figs. 20, 21; Stouge and Bagnoli, 1990, p. 14, 15, pl. 3, figs. 3-7; Dzik, 1994, p. 61, 62, pl. 11, figs. 8-13, text-fig. 4: a; Armstrong, 1997, p. 785, pl. 4, figs. 12-22, text-fig. 6; Löfgren, 1999, p. 178, 180, 182, 184, pl. 1, figs. 1-21, pl. 2, figs. 1-13, pl. 3, figs. 1-7; Wang and Bergström, 1999b, p. 333, pl. IV, figs. 4, 5, 7; Wang and Qi, 2001, pl. 1, fig. 11.

Description.--Collection of this study contains *a*, *d*, and *f* elements. *A* element has posterolateral costae. *D* element is laterally compressed and twists. This element is subdevided into two types; one has relatively long and slender base, and the other has antero-posteriorly flared base. Recurved *f* element has short and flared base.

Material examined.--Nine specimens; 2 *a*, 6 *d*, and 1 *f* elements (IGUT-ag2169, 2170, 1417).

Occurrence.--Beds TAR 38 and 41 in the TAR 2 section, beds ST 4 and 18 in the ST 1 section, bed LAN-79 in the LAN 1 section, and bed LAN-77 in the LAN 2 section.

Remarks.--The specimens fully conform with the description of Löfgren (1999).

Genus ***Decoriconus*** Cooper, 1975

Type species.--Paltodus costulatus Rexroad, 1967.

Decoriconus fragilis (Branson and Mehl, 1933)

Plate 52: 13-17

Decoriconus fragilis (Branson and Mehl, 1933). Cooper, 1976, p. 212, 213, pl. 2, figs. 5, 8, 14-17; Barrick, 1977, p. 53, 54, pl. 2, figs. 15, 21-23; McCracken, 1991, p. 79, 80, pl. 4, figs. 33, 39; Barrick and Klapper, 1992, pl. 2, fig. 5; Farrell, 2003, p. 151, pl. 12, figs. 11, 12, 14, 17; Farrell, 2004, p. 958, pl. 8, figs. 16, 17.

Drepanodus aduncus Nicoll and Rexroad, 1968, p. 35, pl. 7, figs. 11-15; Aldridge, 1972, p. 175, pl. 9, fig. 17.

Paltodus fragilis Branson and Mehl, 1933, p. 43, pl. 3, fig. 3; Rexroad and Nicoll, 1972, pl. 1, figs. 42, 43.

Material examined.--One hundred and Sixteen specimens; 29 *a*, 77 *b*, 6 *b/c*, and 4 *c* elements (IGUT-ag01422, 01440).

Occurrence.--Beds LAN-49, 60 to 62, and 65 in the LAN 1 section.

Remarks.--According to Cooper (1976) and Barrick (1977), this species has apparatus consisting of *a*, *b*, and *c* elements. These elements form a symmetry transition series. *A*, *b*, *b/c*, and *c* elements are recognized in the collection of this study. These are asymmetrical to symmetrical coniform elements, which change their shapes gradually.

Genus ***Drepanodus*** Pander, 1856

Type species.--Drepanodus arcuatus Pander, 1856.

Drepanodus arcuatus Pander, 1856

Plate 35: 6-11

Drepanodus arcuatus Pander, 1856. Lindström, 1955, p. 558, pl. 2, figs. 30-33, text-fig. 3: j; Fahræus, 1966, p. 21, pl. III, fig. 15; Lee, 1975b, p. 84, pl. 1, fig. 13, text-fig. 3: l; Dzik, 1976, text-fig. 17:a, c; Stouge and Bagnoli, 1988, p. 115, pl. 2, figs. 1-6; Dzik, 1994, p. 68, 70, pl. 15, figs. 2-6, text-fig. 8: a, b; Albanesi, 1998b, p. 122, pl. 3, figs. 1-8; Johnston and Barnes, 2000, p. 17, pl. 10, figs. 3, 5, 7-9;

Wang, 2001, p. 352, pl. 1, figs. 2, 6; Zhen, Percival, and Webby, 2003b, p. 52, 53, pl. 3, figs. 1-12.

Material examined.--Sixteen specimens; 16 *q* elements (9 arcuatifrom and 7 sculponeaform) (IGUT-ag1422, 2164 to 2168).

Occurrence.--Beds ST-4 and 5 in the ST section, beds TAR 6 and 13 in the TAR 1 section, beds TAR-27, 28, 31, 36, and 38 in the TAR 2 section, and bed TPP-17 in the TPP section.

Remarks.--Johnston and Barnes (2000) proposed apparatus composition of this genus consisting of *q* and *r* elements. *R* element is oistodiform and *q* elements contains arcuatiform and sculpneaform elements. *Q* element occurs from the study sectoins.

Genus ***Drenaoistodus*** Lindström, 1971

Type species.--*Oistodus forceps* Lindström, 1955

Remarks.--According to Johnston and Barnes (2000), this genus had apparatus consisting of *p*, *q*, and *r* elements. Although Zhen et al. (2003c) described seximembrate appartatus, containing *a*, *b*, *c*, *d*, *e*, and *f* elements, each element is similar in shape, except for oistodiform *e* elements, and it is dificult to distinguish. Therefore, I follow Johnston and Barnes (2000) and classify specimens into *p*, *q*, and *r* elements here.

Drepanoistodus concavus (Branson and Mehl,1933)

Plate 35: 1-5

Drepanodus concavus (Branson and Mehl, 1933). Kennedy, 1980, p. 55-57, pl. 1, figs. 26-34; Repetski, 1982, p. 20, pl. 6, fig. 11.

Drepanoistodus concavus (Branson and Mehl, 1933). Ji and Barnes, 1994, p. 34, 35, pl. 7, figs. 1-7.

Oistodus concavus Branson and Mehl, 1933, p. 59, pl. 4, fig. 6.

Material examined.--Sixty three specimens; 3 *p*, 54 *q*, and 6 *r* elements (IGUT-ag1949 to 1953).

Occurrence.--Beds TAR 3-8, 10, 11, and 14 in the TAR 1 section and beds TAR 22, 23, 27, 28, 32, 3, and 36 in the TAR 2 section.

Remarks.--Ji and Barnes (1994) described this species in detail. The elements from the study sections conforms with their description. Ji and Barnes (1994) recognized *a*, *c*, and *e* elements of this species, and they are correlated with *q*, *p*, and *r* elements of Johnston and Barnes (2000), respectively.

Drepanoistodus costatus (Abaimova, 1971)

Plate 43: 10-13

Drepanodus costatus Abaimova, 1971, p. 490, pl. 10, fig. 6, text-fig. 3.

Drepanodus pitjanti Cooper, 1981, p. 162, pl. 26, figs. 3-5, 7, 8; Watson, 1988, p. 111, pl. 3, figs, 14, 16, 17, pl. 5, fig. 15; Albanesi, 1998b, p. 136, pl. 4, figs. 1-7m text-fig. 16.

Drepanoistodus costatus (Abaimova, 1971). Stait and Druce, 1993, p. 303, figs. 12: l, m, 17: j-n; Zhen, Percival, and Webby, 2003c, p. 191, 194, fig. 15: a-r.

Scolopodus cornutiformis Lee, 1976, p. 172, pl. 2, figs. 18.

Scolopodus ordosensis Wang and Luo, 1984, p. 284, pl. 4, figs. 22, 23.

Material examined.--Twenty specimens; 4 *p* and 16 *q* elements (IGUT-ag2042 to 2045).

Occurrence.--Beds TPP-11, 18, and 27 in the TPP section, and beds LAN-8, 9, 11, and 17 in the LAN 1 section, and bed LAN-77 in the LAN 2 section.

Remarks.--Cooper (1981) described *Drepanodus pitjanti* from the Horn Valley Siltstone in Australia. Zhen et al. (2003c) suggested that this species is a junior synonym of *Drepanoistodus costatus*, and I follow them. Albanesi (1998b) reported a *q* element having short upper margin and straight anterobasal projection of base. He described this element as "*f*" element, which was not reported by Zhen et al. (2003c). This type of elements also occurs from the study sections.

Drepanoistodus forceps (Lindström, 1955)

Plate 39: 3-7

Drepanoistodus forceps (Lindström, 1955). Lindström, 1971, p. 75, figs. 5, 8; Serpagli, 1974, p. 46, pl. 10, figs. 8-12, pl. 21, figs. 9-14; Fåhræus and Nowlan, 1978, p. 459, pl. 1, figs. 22-25; Löfgren, 1978, p. 53, pl. 1, figs. 1-6; Fåhræus and Roy, 1993, p. 21, 22, pl. 2, figs. 9-12; Löfgren, 1995, fig. 7: ag-al; Albanesi, 1998b, p. 136, pl. 3, figs. 19-22; Zhen, Percival, and Webby, 2003b, p. 53, pl. 3, figs. 13-18.

Drepanodus homocurvatus Lindström, 1955, p. 563, pl. 2, figs. 23, 24, 39, text-fig. 4d.

Drepanodus planus Lindström, 1955, p. 565, pl. 2, figs. 35-37, text-fig. 4a.

Oistodus forceps Lindström, 1955, p. 574, pl. 4, figs. 9-13, text-fig. 3m.

Material examined.--Twenty six specimens; 1 *p*, 23 *q*, and 2 *r* elements (IGUT-ag2004 to 2008).

Occurrence.--Beds TAR 36, 38, 42, 45, and 46 in the TAR 2 section.

Remarks.--Zhen et al. (2003b) described asymmetrical drepanodiform, symmetrical to subsymmetrical drepanodiform, and oistodiform elements, which are correlated with *p*, *q*, and *r* elements, respectively. Elements, which occur from the study section, coincides with the description of these three types of element.

Genus ***Erraticodon*** Dzik, 1978

Type species.--Erraticodon balticus Dzik, 1978

Erraticodon patu Cooper, 1981

Plate 40: 15

Erraticodon patu Cooper, 1981, p. 166-168, pl. 32, figs. 1-6, 8; Zhen, Percival, and Webby, 2003b, p. 195-198, figs. 16: a-k, 17: a-o.

Material examined.--One specimen; 1 *f* element (IGUT-ag1816).

Occurrence.--Bed TW15 in the TUW 2 section.

Remarks.--Specimen conforms with *f* (lonchodiniform) element described by Cooper (1981). The element of this study is distinguished from that of *Erraticodon balticus* Dzik, 1978 by having the anterior, posteiror and lateral processes, which are of similar length and bear three to four discrete denticles.

***Erraticodon* sp. A**

Plate 40: 16

Material examined.--One specimens; 1 *b* element (IGUT-ag1797).

Occurrence.--Bed TUS-8 in the TUS section.

Remarks.--Specimen is a hindeodelliform element with a long cusp and denticulate anterolateral and posterior processes, which are distally broken. Cusp has keeled anterolateral and posterior costae, which continue to the processes in their lower part. The poor preservation of the specimen prevents its identification of species.

***Erraticodon* sp. B**

Plate 40: 14

Material examined.--One specimens; 1 *c* element (IGUT-ag2032).

Occurrence.--Bed TPP-27 in the TPP section.

Remarks.--Trichonodelliform element occurs from the study section. This element is symmetrical and has long cusp, two lateral processes, and posterior process. The poor preservation of the specimen prevents its identification of species.

Genus ***Filodontus*** Pyle, Barnes, and Ji, 2003

Type species.--*Scolopodus filosus* Ethiongton and Clark, 1964.

Remarks.--Pyle et al. (2003) founded the genus *Filodontus* and assigned *Filodontus filosus* to this genus. This is the sole species belonging to this genus. Pyle et al. (2003) described two types of element as apparatus of *F. filosus*. Elements of this species are characterized by bearing many extremely fine longitudinal costae from above basal magin to tip of cusp.

Filodontus* sp. cf. *F. filosus (Ethington and Clark, 1964)

Plate 38: 1, 2

Scolopodus filosus Ethington and Clark, 1964. Jones, 1971, p. 63, pl. 5, fig. 11 (only); Repetski, 1982, p. 47, pl. 22, fig. 2.

Description.--Element is slender and simple cone with proclined cusp. Unit slightly curves at one-third to one-half length from basal margin. Cusp gradually tapers toward tip and base is unexpanded and cylindrical. Element has circular cross-section throughout their length. The surface is ornamented by fine longitudinal costae that extend from mid base to tip of cusp and occur on all sides. The costae of distal part are thicher than those of basal part of element. Lower half of base is smooth. Basal margin is straight in lateral view and circular in aboral view.

Material examined.--Four specimens; 4 nongeniculate elements (IGUT-g1986, 1987).

Occurrence.--Bed TAR 46 in the TAR 2 section.

Remarks.--Pyle et al. (2003) described two types of element of *F. filosus*. One is slender form, and the other is stout and squat unit. Both types has reclined cusp and more or less expanded base, which is greater than half length of elements. The element from the study section is proclined and more slender, and has shorter base than those of Pyle et al. (2003). Jones (1971) and Repetski (1982) reported elements similar to the specimen of this study. Stout elements do not occur from the study section.

Genus ***Flajsella*** Valenzuela-Ríos and Murphy, 1997

Type species.--Spathognathodus stygius Flajs, 1967.

Remarks.--Valenzuela-Ríos and Murphy (1997) defined carminiscaphate element with expanded conical cusp as *f* element of species belonging to this genus. The other elements of apparatus of this genus are not entirely reconstructed. On the basis of stratigraphic range of *f* element, Valenzuela-Ríos and Murphy (1997) temporally described *a*, *b*, *c*, *e*, and *g* elements, which co-occur with *f* element.

Flajsella stygia (Flajs, 1967)

Plate 55: 1, 2

Flajsella stygia (Flajs, 1967). Valenzuela-Ríos and Murphy, 1997, p. 139, 140, figs. 8:26-28, 9: 26-30 (only).

Ozarkodina stygia (Flajs, 1967). Lane and Ormiston, 1979, p. 57, 58, pl.1, figs. 45, 46, pl. 2, figs. 10, 11.

Spathognathodus stygius Flajs, 1967, p. 204, 205, pl. 5, figs. 16, 17.

Description.--Carminiscaphate f element has straight anterior blade, which sharply curve at proximal end, in oral view. Anterior blade bears 10 to 16 denticles, with the highest denticles at one-third to one-half length from the anterior end of the blade. Cusp is high and wide, and located at the posterior part. Short posterior carina is nearly straight or gently bent. One to three denticles are poorly developed on posterior carina with adenticulate gap between cusp. Basal flares are symmetrical to asymmetrical in oral view and occupy about one-third to one-half of posterior part of element.

Material examined.--Fifty seven specimens; 57 *f* elements (IGUT-ag2151, 2152).

Occurrence.--Bed LAN-65 in the LAN 1 section.

Remarks.--Specimens, which occur from the study section, almost conform with *f* elements of Valenzuela-Ríos and Murphy (1997), except for slightly short posterior carina and relatively small basal cavity.

Flajsella sigmostygia Valenzuela-Ríos and Murphy, 1997

Plate 55: 4, 5, 7

Flajsella sigmostygia Valenzuela-Ríos and Murphy, 1997, p. 137, 139, figs. 8: 23-25, 9:5-8 (only).

Ozarkodina stygia (Flajs, 1967). Murphy and Matti, 1983, p. 10-12, pl. 3, figs. 1, 2, 7, 8.

Description.--*F* element has nearly straight to gently curved anterior blade bearing 10 to 15 denticles. Several denticles, which located at anterior end, are the highest and the rest gradually descend toward the cusp. Posterior carina is short and gently curves. Two to five denticles are poorly developed on posterior carina. Large basal flares are symmetrical to asymmetrical and occupies about one-third to one-half of posterior part of element.

Material examined.--One hundred and four specimens; 104 *f* elements (IGUT-ag2156 to 2158).

Occurrence.--Bed LAN-65 in the LAN 1 section.

Remarks.--The specimens are distinguished from the elements of *F. stygia* by having more denticles on posterior carina without adenticulate gap between cusp.

***Flajsella* sp. A**

Plate 55: 8, 13

Flajsella streptostygia? Valenzuela-Ríos and Murphy, 1997, fig. 9: 19, 20, 25 (only).

Material examined.--Thirty seven specimens; 37 *g* elements (IGUT-ag2159, 2160).

Occurrence.--Bed LAN-65 in the LAN 1 section.

Remarks.--Valenzuela-Ríos and Murphy (1997) described angulate element as *g* element of several species of *Flajsella*. Asymmetrical angulate elements occurs from the study section and may correspond to *g* element. However, it is difficult to discuss the taxonomy of *Flajsella* sp. A, because all the elements belonging to *Flajsella* are yielded from only one rock sample in this study.

***Flajsella* sp. B**

Plate 55: 3, 6, 9

Flajsella stygmostygia? Valenzuela-Ríos and Murphy, 1997, fig. 9: 9-11 (only).

Material examined.--Sixteen specimens; 8 *b* and 8 *c* elements (IGUT-ag2153 to 2155).

Occurrence.--Bed LAN-65 in the LAN 1 section.

Remarks.--Symmetrical to asymmetrical digyrate elements occurs from the study section. These elements form a symmetry transition series. Valenzuela-Ríos and Murphy (1997) desciribed digyrate elements as *b* and *c* elements of several species of *Flajsella*. However, similarly *Flajsella* sp. A, it is impossible to discuss the taxonomy.

Genus ***Histiodella*** Harris, 1962

Type species.--Histiodella alfrons Harris, 1962.

Histiodella holodentata Ethington and Clark, 1982

Plate 40: 79

HIstiodella holodentata Ethington and Clark, 1982, p. 47, 48, pl. 4, figs. 1, 3, 4, 16; Watson, 1988, p. 115, 116, pl. 4, figs. 15, 20.

Histiodella sinuosa (Graves and Ellison, 1941). Barnes and Poplawski, 1973, p. 776, pl. 1, figs. 17, 18.

Histiodella sp. A Sweet, Ethington and Barnes, 1971, p. 167, pl. 1, fig. 16.

Histiodella sp. 1 Harris, Bergström, Ethington, and Ross 1979, pl. 1, fig. 9.

Material examined.--One specimen; 1 blade-like element (IGUT-ag2025).

Occurrence.--Bed TPP-15 in the TPP section.

Remarks.--Ethington and Clark (1982) recognized blade-like element, symmetrical element, and oistodiform element in apparatus of species of *Histiodella*. Blade-like element is yielded from the study section.

Genus ***Juanognathus*** Serpagli, 1974

Type species.--Scolopodus filosus Ethiongton and Clark, 1964.

Juanognathus variabilis Serpagli, 1974

Plate 39: 1

Acontiodus sp. B Igo and Koike, 1967, p. 17, pl. 2, fig. 15, text-fig. 4: l.

Juanognathus variabilis Serpagli, 1974, p. 49, pl. 11, figs. 1-7, pl. 22, figs. 6-17, text-fig. 8; Landing, 1976, p. 634, pl. 2, figs. 15-17, 19-23; Ethington and Clark, 1982, p. 50, figs. 8-10, 17; Repetski, 1982, p. 27, pl. 8, fig. 9, pl. 9, figs. 1, 2; Wang and Luo, 1984, p. 263, pl. 6, figs. 8, 9; Stouge and Bagnoli, 1988, p. 120, pl. 3, figs. 20, 21; Pohler, 1994, pl. 3, fig. 4; Albanesi, 1998b, p. 126, pl. 5, figs. 10-14; Zhen, Percival, and Webby, 2003b, p. 53, 54, pl. 4, figs. 1-14; Agematsu, Sashida, Salyapongse, and

Sardsud, in press A.

Scolpodus sp. A Igo and Koike, 1967, p. 26, pl. 2, fig. 7, text-fig. 8.

Material examined.--One specimen; 1 *c* element (IGUT-ag2002).

Occurrence.--Bed TPP-21 in the TPP section.

Reamrks.--According to Zhen et al. (2003b), *a*, *b*, *c*, *d*, and *e* elements constitute apparatus of this species. Specimen occurs from the study section is symmetrical juanognathiform element and coincides with the description of *c* element of Zhen et al. (2003b).

Genus ***Jumodontus*** Cooper, 1981

Type species.--*Jumodontus gananda* Cooper, 1981.

Jumodontus gananda Cooper, 1981

Plate 44: 17

Jumodontus gananda Cooper, 1981, p. 170, pl. 31, fig. 13; Nicoll, 1992, p. 216-223, figs. 4-8; Pohler, 1994, pl. 3, figs. 15, 16; Johnston and Barnes, 2000, pl. 4, fig. 22; Zhen, Percival, and Webby, 2003c, p. 198, fig. 18: h-j.

Material examined.--One specimen; 1 *f* element (IGUT-ag2173).

Occurrence.--Bed LAN-77 in the LAN 2 section.

Remarks.--Nicoll (1992) revised a diagnosis of this species and described coniform and ramiform elements, which are assigned to *a*, *b*, *c*, *d*, *e*, *f*, and *g* element. Stout ramiform element is yielded from the study section. The specimen conforms wtih *f* element of Nicoll (1992).

Genus ***Monocostatus*** Miller, 1980

Type species.--*Acodus sevierensis* Miller, 1969.

Monocostatus sevierensis (Miller, 1981)

Plate 1: 6, 7

Acodus sevierensis Miller, 1969, p. 418, pl. 63, figs. 25-31 (only).

Acontiodus (*Semiacontiodus*) *unicostatus* Miller, 1969, p. 421, pl. 64, figs. 49-54 (only).

Monocostatus sevierensis (Miller, 1969). Miller, 1981, p. 27, pl. 2, figs, 8, 9, text-fig. 4u; Landing, Westrop, and Hernick, 2003, fig. 7: 14, 18.

Material examined.--Six specimens; 1 *a/b* and 5 *c* elements (IGUT-ag1941, 1942).

Occurrence.--Bed TAR-3, 6, and 9 in the TAR 1 section.

Remarks.--Specimens occur from the study section contain symmetrical and subsymmetrical elements. These elements form a symmetry transition series and conform with the description of Miller (1981).

Genus ***Oepikodus*** Lindström, 1955

Type species.--Oepikodus smithensis Lindström, 1955.

***Oepikodus* sp. A**

Plate 43: 5, 6

Material examined.--Three specimens; 1 *b*, 1 *d*, and 1 *e* element (IGUT-ag2037, 2038).

Occurrence.--Bed LAN-70 in the LAN 2 section.

Remarks.--On the basis of natural assemblages and discrete elements of *Oepikodus evae* (Lindström, 1955), Stewart and Nicoll (2003) defined apparatus of *Oepikodus* as septimembrate. *A*, *b*, *c*, and *d* elements of species belonging to *Oepikodus* are qaudriramate or modified quadriramate forms. *E* element is geniculate makellate element. *F* and *g* element are pastinate element. In this study, quadriramate *b* and *d* elements and geniculate *e* element are yielded from the LAN 2 section.

Genus ***Oistodus*** (Pander, 1856)

Type species.--Ooistodus lanceolatus (Pander, 1856)

***Oistodus* sp. A**

Plate 41: 17

Drepanoistodus? *venustus* (Stauffer, 1935). Löfgren, 1978, p. 57, pl. 1, figs. 19, 10.

Drepanoistodus? aff. *venustus* (Stauffer, 1935). Löfgren, 2003, fig. 7ac (only).

Drepanoistodus cf. *D. venustus* (Stauffer, 1935). Viira, Löfgren, Mägi, and Wickström, 2001, fig. 9h.

Oistodus abundans Branson and Mehl, 1933. Rhodes, 1953, p. 294, pl. 21, figs, 91, 92.

Oistodus venustus Stauffer, 1935. Rhodes, 1953, p. 295-296, pl. 22, figs. 168-170; Sweet and Bergström, 1962, p. 1232, pl. 168, figs. 10, 11; Hamar, 1964, p. 269, pl. 3, figs. 3-6, 9, 11, test-fig. 6.10; Webers, 1966, p. 34-35, pl. 2, fig. 18, 19; Bergström and Sweet, 1966, p. 341-342, pl. 35, fugs. 20, 21.

"*Oistodus*" sp. A. Leslie, 2000, p. 1136, figs. 3.30-3.32.

Paltodus? *venustus* (Stauffer, 1935). Dzik, 1994, p. 76-78, text-fig. 12: c (only).

Material examined.--Two specimens; 2 geniculate elements (IGUT-ag1806).

Occurrence.--Bed TW10 in the TUW 2 section.

Remarks.--According to Leslie (2000), his "*Oistodus*" sp. A is similar to *Oistodus venustus* (Stauffer, 1935), but they are different species. "*O.*" sp. A has more strongly compressed cusp with more marked costa than *O. venustus*, and is divided into two morphotypes, A1 and A2. Specimen of this study has laterally compressed and conspicuously costate cusp. An anterobasal corner is rounded and forms about 80°. Basal margin turns up at a position of two third from posterior end. These characteristics correspond to those of the type A1 of "*O.*" sp. A (Leslie, 2000).

Genus ***Oulodus*** Branson and Mehl, 1933

Type species.--*Cordykodus serratus* Stauffer, 1930

Oulodus sp. A

Plate 53: 8, 9

Material examined.--Ten specimens; 1 *a*, 5 *b*, and 3 *c* elements (IGUT-ag2130, 2131).

Occurrence.--Bed ST- 20 in the ST 2 section and beds LAN-56, 57, 60-62, 64, and 65 in the LAN 1 section.

Remarks.--Sweet (1988) described *a*, *b*, *c*, *e*, *f*, and *g* elements as apparatus of species of this genus. Three types of dygirate elements occurs from the study section and constitute a symmetry transition series.

Genus ***Ozarkodina*** Branson and Mehl, 1933

Type species.--Ozarkodina typica (Branson and Mehl, 1933)

Reamrks.--Species of this genus possesses sexi- or septimembrate appratus, consisting of cariminate *f* element, angulate *g* element, bipennate *e* element, and *a*, *b*, *c*, and *d* elements of a symmetry transition series (Sweet, 1988). The symmetry transition series contains alate, dygirate, and bipennate elements.

Ozarkodina excavata excavata (Branson and Mehl, 1933)

Plate 54: 6-11

For synonymy, see Farrell (2003).

Additions to the above synonymy:

Ozarkodina excavata excavata (Branson and Mehl, 1933). Farrell, 2003, p. 135, pl. 6, figd. 10-21; Mawson, Talent, Molloy, and Simpson, 2003, pl. 3, figs. 1-19, pl. 4, figs. 1-15.

Material examined.--One hundred and fourteen specimens; 10 *a*, 26 *b*, 17 *c*, 6 *e*, 39 *f*, and 16 *g* elements (IGUT-ag2143 to 2148).

Occurrence.--Beds ST-20 to 23 in the ST 2 section and beds LAN-56, 57, 60 to 62, 64, and 65 in the LAN 1 section.

Remarks.--*F* element of this species occurs from the study section. Unit is bilaterally symmetrical to asymmetrical and has various denticles in size and number. These elements are distinguished by having obviously low anterior and posterior blades and relatively small basal flares from *f* elements of *O. renschendensis remscheidensis* and *O. remscheidensis eosteinhornensis*. *G* element of *O. excavata excavata* is angulate form. The element is elongated antero-posteriorly, compared with the other species of this genus.

Ozarkodina remscheidensis (Ziegler, 1960)

Ozarkodina remscheidensis eosteinhornensis (Walliser, 1964)

Plate 54: 1-5

For synonymy, see Mawson et al. (2003).

Additions to the above synonymy:

Ozarkodina remscheidensis eosteinhornensis (Walliser, 1964). Mawson, Talent, Molloy, and Simpson, 2003, p. 89, 90, pl. 1, figs. 1-3, pl. 2, figs. 20, 21.

Description.--*F* element is carminate form. Cusp is located at one-third length from posterior end of unit. Anterior and posterior blades bear 5 to 7 and 4 to 5 denticles, respectively. Height and width of denticles are generally constant, except for cusp. Some elements have denticule line, which is bilaterally symmetrical in oral view. The others have subsymmetrical denticle line, whose posterior part slightly curves inwardly. Basal flares are various in shape and size. Angulate *g* element is laterally compressed and has conspicuous cusp. Denticles on anterior and posterior blades are 6 to 8 and 4 to 5, respectively, and descend their height toward each distal part. Basal cavity is small and shallow.

Material examined.--Thirty five specimens; 27 *f* and 8 *g* elemetns (IGUT-ag2138 to 2142).

Occurrence.--Bed LAN-64 in the LAN 1 section.

Remarks.--Number of denticles, shape and size of basal flares, and symmetry of unit of the *f* element are various. However, this element commonly has denticles, which are regular in width and height, in contrast with that of *O. r. remscheidensis*. *G* element of *O. r. eosteinhornensis* differs from that of *O. r. remscheidensis* in having more remarkable cusp and realtively low anterior and posterior denticles.

Ozarkodina remscheidensis remscheidensis (Zeigler, 1960)

Plate 53: 10, 11, 13, 14

For synonymy, see Mawson et al. (2003).

Additions to the above synonymy:

Ozarkodina remscheidensis remscheidensis (Ziegler, 1960). Mawson, Talent, Molloy, and Simpson, 2003, p. 89, 90, pl. 1, figs. 1-3, pl. 2, figs. 20, 21.

Description.--*F* element is carminate and nearly straight in oral view. Anterior and posterior blades bear 7 to 8 and 4 to 5 denticles, respectively. These denticles are irregular in height and width. Lower margin of some specimens is straight in lateral view. Anterior and posterior lower margins of other specimens form an angle of 160 to 140° in lateral view. Basal flares are various in shape and size. *G* element resembles that of *O. r. eosteinhornensis*. Anterior and posterior blades bear 8 to 11 and 5 to 10 fine denticles, respectively. *A* and *b* elements are bipennate and digyrate units, forming a symmetry transition series. *E* element is digyrate form.

Material examined.--Fourty specimens; 5 *a*, 2 *b*, 2 *e*, 21 *f*, 10 *g* elements (IGUT-ag2132 to 2135).

Occurrence.--Beds LAN-56, 57, 62, and 64 in the LAN 1 section.

Remarks.--The *f* element is characterized by having denticles with irregular height and width. This characteristics discriminate *O. r. remscheidensis* from *O. r. eosteinhornensis*. *G* element of *O. r.*

remscheidensis bears higher dentilces than that of *O. r. eosteinhornensis*.

Genus ***Panderodus*** Ethington, 1959

Type species.--*Paltodus unicostatus* Branson and Mehl, 1933.

Remarks.--According to Löfgren (1978), the apparatus of the earliest species of this genus had bimembrate apparatus consisting of slender coniform elements. Late Ordovician species of *Panderodus* have quinquimembrate skeletal apparatuses, and the apparatus of fully evolved species was probably seximembrate (Sweet, 1979). Nowlan and Barnes (1981) suggests that apparatuses of this genus include several patterns.

Panderodus gracilis (Branson and Mehl, 1933)

Plate 45: 6-9

Paltodus compressus sp. Branson and Mehl, 1933, p. 109, pl. 8, fig. 19.

Paltodus gracilis sp. Branson and Mehl, 1933, p. 108, pl. 8, figs. 20, 21.

Panderodus gracilis (Branson and Mehl, 1933). Ethington, 1959, p. 285, pl. 39, fig. 1; Sweet and Bergström, 1962, p. 1233, text- fig. 1: h; Bergström, 1964, p. 30-32, text-fig. 16; Fåhræus, 1966, p. 26, pl. 3, fig. 14a-b; Serpagli, 1967, p. 85-87, pl. 23, figs. 3-5; Orchard, 1980, p. 23, pl. 3, figs. 1, 2, 8, 10, 14, 15, 19, 22, 23, 26, 32, text-fig. 4: b; Ferretti and Schonlaub, 2001, pl. 2, figs. 21, 22; Wang and Qi, 2001, pl. 1, fig. 16; Agematsu, Sashida, Salyapongse, and Sardsud, in press C.

Description.--Similiform element is gradually curved with maximum curvature forming approximately 90-120° at half length of unit from basal margin. Longitudinal furrows run each lateral side and broadly convex, smooth anterior face form anterolateral costae. Posterior part of base is strongly compressed laterally. Basal margin forms an angle of 45-60° with upper margin.

Material examined.--Fifty three specimens (IGUT-ag1001, 1060, 1061, 1154).

Occurrence.--Beds ST-1 to 3 in the ST 1 section and LAN- 27 to 30, 33, 35, 39, 79, and 80 in the LAN 1 section.

Remarks.--Orchard (1980) illustrated five midcone sections of elements and discussed four morphotypes of this species. The number of specimens and their preservation in this study are not adequate for analysis of the apparatus.

Panderodus langkawiensis (Igo and Koike, 1967)

Plate 51: 1-4

Acodus langkawiensis Igo and Koike, 1967, p. 12, pl. 1, figs. 19, 20, text-fig. 4: b.

Drepanodus malayensis Igo and Koike, 1967, p. 18, pl. 1, figs. 1, 2, text-fig. 5: h.

Description.--On the basis of curvature, simple-coned specimens are distinguished into two types. I temporally nominate these specimens to *p* and *q* elements. *P* element has proclined to erect cusp and relatively long base. *Q* element is strongly reclined, and its base is short and flares posteriorly. All the specimens are stout and asymmetrical units with posterolateral furrow running from basal margin to tip of cusp on one lateral side. Anterior margin is narrowly rounded in cross-section at cusp, and smoothly arcs from anterobasal corner to tip of cusp in lateral view. Posterior margin is sharply edged. Some specimens have broadly rounded costa between the furrow and anterior margin. The other lateral face is smooth. Anterior face of base is broadly convex with conspicuous anterior carina, which is sharply rounded. Elements of this species are generally characterized by markable and rounded rim along basal margin. Upper edge of the rim is ornamented with a row of short, longitudinal striations. Posterior margin of base slightly projects just above basal rim in lateral view. Conical basal cavity is pointed near anterior margin. Outline of basal margin is oval and slightly notched by lateral furrow.

Material examined.--Seventy specimens, 42 *p* and 58 *q* elements (IGUT-ag2091 to 2094).

Occurrence.--Beds ST- 20 and 21 in the ST 2 section and beds LAN- 49 to 51 and 53 in the LAN 1 section.

Reamrks.--Igo and Koike (1967) described *Acodus langkawiensis* and *Drepanodus malayensis* from the Langkawi Islands. These species correspond to *q* and *p* elements of *Panderouds langkawiensis*, respectively. Elements of *P. langkawiensis* are slender coniform element, and bear lateral furrow and longitudinal striation. These characteristics suggest that this species belongs to *Panderodus*. Although *P. langakwiensis* is similar to *Panderouds* sp. cf. *P. serratus* Cooper, 1975, *P*. sp. cf. *P. serratus* has markably long cusp and base with broadly rounded anterior margin. Mabillard and Aldridge (1985) illustrated a coniform element with slender, long base as *P. langkawiensis*. However, slender elements of *P. langkawiensis* do not occur from the study section.

Panderodus nogamii (Lee, 1975a)

Plate 44: 1-7

Panderodus sp. Serpagli, 1974, p. 59, pl. 24, figs. 12, 13, pl. 30, figs., 12, 13.

Panderodus nogamii (Lee, 1975a). Cantrill and Burrett, 2003, p. 410-415, pl. 1, figs. 1-16; Zhen, Barnes and Cooper, 2003a, p. 16, pl. 5, figs. 1-5.

Parapanderodus nogamii (Lee, 1975a). Watson, 1988, p. 124, 125, pl. 3, figs. 1, 6.

Parapanderodus paracornuformis (Ethington and Clark, 1982). Albanesi, 1998b, p. 116, 117, pl. 12, figs. 8-10, 12, 13 (only), text-fig. 9.

Protopanderodus nogamii (Lee, 1975a). Zhen, Percival, and Webby, 2003c, p. 207, 209, fig. 23: a-q.

Protopanderodus primitus (Druce). Cooper, 1981, p. 174, 175, pl. 27, figs. 3, 4; Agematsu, Sashida, Salyapongse, and Sardsud, in press A.

Protopanderodus? *primitus* Cooper, 1981. Stait and Druce, 1993, p. 307, 308, text-figs. 13: a-c, 18: d, e, g-k.

Scolopodus cf. *bassleri* (Furnish, 1938), Igo and Koike, 1967, p. 23, pl. 3, fugs. 7, 8, text-fig. 6: b.

Scolopodus nogamii Lee, 1975a, p. 179, pl. 2, fig. 13, text-fig. 3: l.

Description.--Elements of this species are various in symmetry and curvature of unit. Several apparatus plans have been proposed (Cooper, 1981; Stait and Druce, 1993; Cantrill and Burrett, 2003; Zhen et al., 2003c). On the basis of notation of Barnes et al. (1979) and Ji and Barnes (1994), I discribe this species here. Elements are classified into *a*, *b*, *c*, *f*, and *g* elements and have proclined to reclined cusp and longitudinal furrows, which are developed from basal margin to tip of cusp on both lateral faces. Element is ornamented with longitudinal striation, which is conspicuous at base.

Symmetrical *c* element has proclined to erect cusp. Anterior margin is broadly convex and borderd by rounded anterolateral costae. Lateral faces bear deep furrows. Posterior margin is rounded. Posterobasal part of base projects downwardly. Outline of basal margin is modified oval with flattened anterior end and narrowly rounded posterior end. Some specimens bear a shallow groove on a lateral side, which is most remarkable at point of maximum curvature and disappear before reaching basal margin and tip of cusp. *B* element is similar to *c* element, but is asymmetrical and inwardly twists. Symmetrical to subsymmetrical *a* element has proclined to erect cusp and unexpanded base. Lateral furrows are shallower than those of *b* and *c* elements. Anterior and posterior margins are rounded. Basal margin is oval, which is notched by lateral furrows, in aboral view. Some subsymmetrical specimens bend inwardly.

Symmetrical to subsymmetrical *f* element is strongly compressed laterally. Proclined to erect cusp has narrowly rounded anterior margin and keeled posterior margin. Longitudinal furrows run from basal margin to tip of cusp along anterior margin on lateral faces. Short base is unexpanded with narrowly rounded anterior and posterior margins. Aboral outline of basal margin is narrow ellipse. Some elements twist inwardly. Symmetrical to subsymmetrical *g* element resembles *f* element. But cusp of *g* element is erect to reclined and weakly compressed. Base is expanded antero-posteriorly.

Materials.--Ninety two specimens; 32 *a* elements, 23 *b* elements, 17 *c* elements, 6 *f* elements, and 15 *g* elements (IGUT-ag2052 to 2058).

Occurrence.--Beds TPP-11, 17, 18, 21, 22, 24, 27, and 28 in the TPP section, beds TUS-5, 7, 8, 10, and 11 in the TUS section, beds LAN-6 to 8, 10 to 12, 16, 23, and 24 in the LAN 1 section, and beds LAN-76 to78 in the LAN 2 section.

Remarks.--Cantrill and Burreitt (2003) described this species as a member of *Panderodus*. However, Zhen et al. (2003c) relegated this species to *Protopanderodus* Lindström, 1971. According to Cantrill and Burreitt (2003), species of *Panderodus* is generally defined by following characteristics of its elements; longitudinal furrows on lateral faces and longitudinal striations on surface, especially at base. Zhen et al. (2003c) concluded that deep, lateral furrows of this species disappear just above basal margin and differ from a panderodontid furrow. However, the specimens of this study bear panderodontid furrows and more conspicuous striations than those of *Protopanderodus*. Therefore, I describe this species as *Panderodus*.

Panderodus* sp. cf. *P. serratus Rexroad, 1967

Plate 49: 13, 14

Material examined.--Ninety nine specimens; 99 nongeniculate elements (IGUT-ag01001 to 01003, 01059 to 01066).

Occurrence.--Beds LAN-49, 50, 52, and 55 in the LAN 1 section.

Remarks.--Element has strongly recurved cusp and long, slender base. These elements are similar to costate element of *Panderodus serratus* Rexroad, 1967 and *P.* sp. cf. *P. serratus*, described by Cooper (1975). However, serratid elements, which are one of the characteristic elements of *P. serratus*, are not found in the collection of this study.

Panderodus unicostatus (Branson and Mehl, 1933)

Plate 52: 10-12

For synonymy, see Farrell (2003).

Additions to the above synonymy:

Panderodus unicostatus (Branson and Mehl, 1933). Farrell, 2003, p. 122, 123, pl. 1, fig. 2; Mawson, Talent, Molly, and Simpson, 2003, pl. 5, figs. 7-9; Farrell, 2004, p. 959, pl. 4, figs. 10-13.

Material examined.--Sixty nine specimens; 69 *a/b* elements (IGUT-ag2115 to 2117).

Occurrence.--Beds LAN-49 to 54, 60 to 62, and 64 in the LAN 1 section.

Remarks.--According to Cooper (1976) and Barrick (1977), apparatus of this species consists of simplexiform *e* element and costate *a*, *b*, and *c* elements, forming a symmetry transition series. Element from the study section is subsymmetrical to asymmetrical and bears longitudinal grooves on a lateral face. These specimes conform with *a* and *b* elements described by Barrick (1977).

Panderodus sp. A

Plate 45: 5, 10

Description.--Cusp is proclined with maximum curvature at half length of unit from basal margin. Element has longitudinal furrows on both sides and broadly convex, smooth anterior margin. Posterior part of base is strongly compressed laterally. Basal margin is rimmed by thick and smooth lateral ridge.

Material examined.--Four specimens; 4 nongeniculate elements (IGUT-ag 01423, 01441, 01662).

Occurrence.--Beds ST-2, 4, 5, and 10 in the ST 1 section.

Reamrks.--The specimens are similar to *P. gracilis* in several respects, such as furrows on each lateral side and outline of base in aboral view. However, the short and stout unit with rimmed base distinguishes the specimens from *P. gracilis*.

Genus ***Pandorinellina*** Müller and Müller, 1957

Type species.--*Pandorina insita* Stauffer, 1940.

Pandorinella sp. A

Plate 54: 12, 13

Description.--Carminate element occurs from the study section. *F* element is nearly straight to gently curved inwardly. Anterior blade has the "highest denticle set" consisting of conspicuous large three denticles at anterior end. Basal flares are symmetrical and asymmertical. Some specimens bear a denticle on basal flare. Posterior and anterior lower margins form an angle of 120 to 160° in lateral view.

Material examined.--Three specimens; 3 *f* elements (IGUT-ag2149, 2150).

Occurrence.--Bed LAN-64 in the LAN 1 section.

Remarks.--Farrell (2003) classified species of this genus into the optima, exigua, and steinhornensis groups. The elements of this study have the "highest denticle set " at anterior end. The posterior-most denticle within this set is the highest. This characteristics suggest that this species belongs to the exigua group.

Genus ***Parapanderodus*** Stouge, 1984

Type species.--*Parapanderodus asymmetyicus* Barnes and Poplawski, 1973

***Parapanderodus striatus* (Graves and Ellison, 1941)**

Plate 37: 1

Drepanodus striatus Graves and Ellison, 1941, p. 11, pl. 1, figs. 3, 12.

Parapanderodus striatus (Graves and Ellison, 1941). Stouge, 1984, p. 67, pl. 10, figs. 1-3; Ji and Barnes, 1994, p. 49, 50, pl. 21, figs. 1-10, text-fig. 31a; Albanesi, 1998b, p. 117, pl. 7, fig. 27

Scolopodus gracilis Ethington and Clark, 1964, p. 699, pl. 115, figs. 2-4, 8, 9.

"*Scolopodus*" *gracilis* Ethington and Clark, 1982, p. 100, 101, p. 11, fig. 28 (only).

Scolopodus paracornuformis Ethington and Clark, 1982, p. 102, pl. 11, fig. 21, text-fig. 25.

Scolopodus quadraplicatus Branson and Mehl, 1933. Ethington and Clark, 1964, p. 699, 700, pl. 115, figs. 12, 25.

Scolopodus striolatus Harris and Harris, 1965, p. 38, pl. 1, fig. 6.

Scolopodus variabilis Ethington and Clark, 1964, p. 701, pl. 15, fig. 14 (only).

Material examined.--One specimens; 1 *c* element (IGUT-ag1972).

Occurrence.--Bed TAR 30 in the TAR 2 section.

Remarks.--Ji and Barnes (1994) described *a*, *b*, *c*, and *e* elements as aparatus of this species. Element of this study is bilaterally symmetrical form and characterized by widely flattened posterior carina with shallow median groove. This element is identified as *c* element of Ji and Barnes (1994).

Genus ***Paroistodus*** Lindström, 1971

Type species.--*Oistodus parallelus* Pander, 1856

Remarks.—Two element forms, drepanodontiform and oistodontiform, have been described as an apparatus of the *Paroistodus* species (e.g., Löfgren, 1978). Löfgren (1997) subdivided drepanodontiform elements in her huge collection into 6 types. However, Johnston and Barnes (2000) redescribed a *Paroistodus* apparatus consisting of two element types, *r* (oistodiform) and *q* (drepanodiform) elements. I follow their concept in this paper, because drepanodiform elements exhibit a gradual change of their morphology and subdivision of those elements is quite difficult.

Paroistodus originalis (Sergeeva, 1963)

Plate 41: 13-16

Oistodus originalis Sergeeva, 1963, p. 98, pl. 7, figs, 8, 9, text-fig. 4.

Paroistodus parallelus (Pander, 1856). Johnston and Barnes, 2000, p.31, 32, pl. 10, figs. 10, 15-17, 20 (only).

Paroistodus originalis (Sergeeva, 1963). Lindström, 1971, p. 48, 49, figs. 8, 12; Löfgren, 1978, p. 69-71, pl. 1, figs. 22-25, text-fig. 28; An, Du and Gao, 1985, pl. 5, figs. 4, 5, 22; Stait and Druce, 1993, p. 306, text-fig. 18: f; Löfgren, 1994, fig. 6: 13-16; Löfgren, 1995, fig. 7: u-y; Löfgren, 1997, p. 926, 927, pl. 1, figs. 13-16, 18-20, 22-33, text-fig. 5: h-o; Albanesi, 1998b, p. 143, 144, pl. 8, figs. 17-23, test-figs. 17, 18; Bednarczyk, 1998, pl. 1, figs. 6, 18; Lehnert, Keller and Bordonaro, 1998, p. 56, pl. 2, fig. 10, pl. 3, fig. 15; Wang and Bergström, 1999a, pl. 2, figs. 6, 7; Wang and Bergström, 1999b, p. 339, 340, pl. 2, figs. 6, 11, 12; Albanesi and Barnes, 2000, fig. 5: 20-24; Viira, Löfgren, Mägi and Wickström, 2001, fig. 6: l, m.

Materials.--Thirty two specimens; 16 *r* elements, 16 *q* elements (IGUT-ag1814, 1822, 1831, 1834).

Occurrence.--Bed TUW-15 in the TUW 2 section.

Remarks.--Definitions of *Paroistodus parallelus* and *P. originalis* are still in dispute. These species have been distinguished mainly by a presence of longitudinal costae on lateral faces. However, some researchers regard this morphological feature as a variation in a species (e.g., Johnston and Barnes, 2000). I consider that there is some distinction of biostratigraphic distribution between *P. parallelus* and *P. originalis*, because our specimens are obtained from a level and consists of only acostate element.

***Paroistodus* sp. A**

Plate 38: 12

Material examined.--One specimens; 1 *q* element (IGUT-ag1997).

Occurrence.--Bed 46 in the TAR 2 section.

Remarks.--Element is drepanodontiform with erect cusp. Cusp is characterized by sharp carina on inner lateral face. However, the identification of species is difficult because only one element is found in the collection of this study.

Genus ***Periodon*** Hadding, 1913

Type species.--*Periodon aculeatus* Hadding, 1913

Remarks.—I follow the concept of Johnston and Barnes (2000), who described *a*, *b*, *c*, *e*, *f*, and *g* elements in apparatus of *Periodon* species.

Periodon aculeatus Hadding, 1913

Plate 41: 9-12

Periodon aculeatus Hadding, 1913, p. 33, pl. 1, fig. 14; Lindström, 1955, p. 110, pl. 22, figs. 10, 11, 14-16, 35; Sweet and Bergström, 1962, p. 1235, pl. 171, figs. 3, 9; Bradshaw, 1969, p. 1159, 1160, pl. 137, figs. 1-6; Barnes and Poplawski, 1973, p. 780, 781, pl. 5, figs. 15-18; Landing, 1976, p. 636, pl. 3, figs. 3-6, 14; Dzik, 1976, figs. 34i-r; Löfgren, 1978, p. 74, 75, pl. 10, fig. 1, pl. 11, figs. 12-26; Wang and Luo, 1984, p. 271, 272, pl. 6, fogs. 10-16, pl. 9, fig. 32, pl. 11, fig. 5; Armstrong, 1997, p. 774, 775, pl. 2, figs. 13-21, text-fig. 3; Albanesi, 1998b, p. 170, 171, pl. 15, figs. 16, 17, pl. 16, figs.19, 20; Wang and Bergström, 1999a, pl. 2, fig. 20; Johnston and Barnes, 2000, p. 32-35, pl. 13, figs. 12, 13, 17, 18, 20-31, pl. 14, figs. 1-7, text-figs. 4, 5; Wang and Qi, 2001, pl. 2, figs. 8-11; Pyle and Barnes, 2003, figs. 15-6, 15-7, 15-8.

Material examined.--Six specimens; 2 *a*, 3 *b*, and 1 *e* elements (IGUT-ag1807, 1809, 1837, 1839).

Occurrence.--Beds TUW-10, 13, 15, and 16 in the TUW 2 section.

Remarks.--*A*, two types of *b* (ligonodiniform and cladognathiform), and *e* elements are included in the collection of this study. *E* element bears three denticles on anterior margin at base. Ramiform elements (*a* and *b*) have acute anterobasal corner, and their basal margins curve at an angle of 90° under cusp. On the basis of the characteristics of *Periodon flabellum* (Lindström, 1955) and *P. aculeatus*, suggested by Johnston and Barnes (2000), the specimens of this study are identified with *P. aculeatus*.

Periodon sp. A

Plate 44: 12-14

Material examined.--Eight specimens; 2 *a*, 1 *b*, 3 *f*, and 1 *g* elements (IGUT-ag2063 to 2065).

Occurrence.--Beds LAN-18, 22, 23, and 24 in the LAN 1 section.

Remarks.--Specimens are digyrate and bipennate form and laterally comprepssed. These elements are correlated with *a*, *b*, *f*, and *g* elements, but identification of species is difficult due to their poor preservation.

Periodon sp. B

Plate 40: 17

Material examined.--One specimens; 1 *b* element (IGUT-ag2033).

Occurrence.--Bed TPP-17 in the TPP section.

Remarks.--Element is bipennate form with flattened anterior face and denticulated posterior process. This element is correlated with *b* elements, but the preservation are not adequate for analysis of the apparatus.

Genus ***Plectodina*** Stauffer, 1935

Type species.--Prioniodus aculeatus Stauffer, 1930

Plectodina onychodonta An and Xu, 1983 (in An et al., 1983)

Plate 40: 1

Plectodina onychodonta n. sp. An and Xu, 1983 (An et al., 1983), p. 121, pl. 23, figs, 1-16, pl. 24, figs. 1-15, pl. 25, figs. 4, 7, text-fig. 13:19-24.

Description.--Element is prioniodiniform unit. Lateral faces bear moderately prominent median ridge. Denticles are laterally compressed, indiscrete, and pointed acutely with sharp-edged antero-posterior margins. Anterior denticles are erect and decrease their size toward anterior end. Main cusp is largest denticle, which is slightly directed posteriorly and inwardly. Aboral side is entirely grooved, with prominent lateral expansion developed beneath main cusp.

Materials.--Two specimens: 2 prioniodiniform elements (IGUT-ag2019).

Occurrence.--Bed TPP 18 in the TPP section.

Remarks.-- An et al. (1983) recognized six morphotypes in the apparatus of this species, subcordylodontiform, crytoniodontiform, dichognathiform, prioniodiniform, trichonodelliform, and zygognathiform elements. Two prioniodiniform elements occur from the TPP section.

Genus ***Prioniodus*** Pander, 1856

Type species.--Prioniodus elegans Pander, 1856

Prioniodus amadeus Cooper, 1981

Plate 44: 11

Prioniodus amadeus Cooper, 1981, p. 173, 174, pl. 31, figs. 1-3, 5, 6, 8, 9.

Materials.-- Eight specimens: 4 *b* and 4 *c* elements (IGUT-ag2062).

Occurrence.--Beds LAN-8, 10, 11, and 24 in the LAN 1 section.

Remarks.--Cooper (1981) described *a*, *b*, *c*, *e*, and *f* elements as apparatus of this species. Elements, which occurs from the study section, are symmetrical tichonodelliform and asymmetrical tetraprioniodontiform units. These elements corresponds to *b* and *c* elements, which constitute a symmetry transition series

Genus ***Protopanderodus*** Lindström, 1971

Type species.--Acontiodus rectus Lindström, 1955

Remarks.—I use the apparatus reconstruction of McCracken (1989) and Johnston and Barnes (2000), which includes *a/b* and *c*, and e elements. *A/b* and *c* elements form a symmetry transition series. Most species of this genus have a trimembrate apparatus (Johnston and Barnes, 2000).

Protopanderodus gradatus Serpagli, 1974

Plate 41: 1-4

Protopanderodus gradatus Serpagli, 1974, p. 75-77, pl. 15, figs. 5-8, pl. 26, figs. 11-15, pl. 30, figs. 1a, 1b, text-fig. 17; Landing, 1976, p. 639, pl. 4, figs. 8, 9, 11, 12; Ethington and Clark, 1982, p. 84, 85, pl. 9, figs. 16, 17, 20 ,21; An, Du and Gao, 1985, pl. 5, figs.2, 3, 15; Stouge and Bagnoli, 1988, p. 136, 137, pl. 14, figs. 9-12; Pohler, 1994, pl. 6, fig. 5; Albanesi, 1998b, p. 128, 129, pl. 11, figs. 13-16, pl.

15, figs. 12, 13, text-fig. 14: B; Lehnert, Keller and Bordonaro, 1998, p. 57, pl. 3, figs. 4, 5; Johnston and Barnes, 2000, p. 40, pl. 8, figs. 7-9, test-fig. 6: 7-11; Zhen, Percival, and Webby, 2003b, p. 204, 207, fig. 22: a-k.

Materials.--Eighty specimens; 63 *a/b*, 10 *c*, and 7 *e* elements (IGUT-ag1803, 1808, 1811, 1823).

Occurrence.--Beds TUW1-3 in the TUW 1 section and beds TUW10-17 in the TUW 2 section.

Remarks.--*A/b* and *c* elements in the collection of this study are correlated with "*Scolopodus*"-like element of Serpagli (1974), which comprises a symmetry transition series, and their forms change gradually. *Protopanderodus* sp. cf. *P. gradatus* described by Johnston and Barnes (2000) differs from *P. gradatus* in having asymmetrical *a/b* (acontiodontiform) element in its apparatus. The specimens of this study do not contain acontiodontiform-type *a/b* elements.

Protopanderodus leonardii Serpagli, 1974

Plate 41: 5, 6

Protopanderodus leonardii Serpagli, 1974, p. 77-79, pl. 16, figs. 1-4, pl. 27, figs. 12-16, text-fig. 18; Albanesi, 1998b, p. 129, pl. 11, figs. 1-4, text-fig. 14: E; Johnston and Barnes, 2000, p. 40, 41, pl. 9, figs. 22, 26-28, test-fig. 7: 1, 2, 6, 9; Zhen, Percival, and Webby, 2003b, p. 207, fig. 22: l-r.

Materials.--Five specimens; 5 *a/b* elements (IGUT-ag1826, 1838).

Occurrence.--Bed TUW-15 in the TUW 2 section and bed LAN-18 in the LAN 1 section.

Remarks.--Element is bilaterally asymmetrical and bears posterolateral costa on a lateral face. The specimen corresponds to asymmetrical elements of the "*Acontiodus*"-like element (Serpagli, 1974) and the *a/b* element of Johnston and Barnes (2000). *C* and *e* elements of Johnston and Barnes (2000) are not recognized due to the small collection of this study.

Protopanderodus liripipus Kennedy, Barnes and Uyeno, 1979

Plate 49: 7-11

Protopanderodus liripipus n. sp. Kennedy, Barnes, and Uyeno, 1979, p. 546-550, pl. 1, figs. 9-19; McCracken, 1989, p. 18-20, pl. 3, figs. 15, 16, 18, 20-25, text-fig. 3: g-j; Dzik, 1994, p. 74, 75, pl. 14, figs. 6, 7, text-fig. 11: c; Leslie, 2000, fig. 6: 19-24; Wang and Qi, 2001, pl. 1, figs. 5, 22; Agematsu, Sashida, Salyapongse, and Sardsud, in press C.

Protopanderodus insculptus (Branson and Mehl, 1933). Dzik, 1976, p. 443, text-fig. 16: h, k.

Description.--Specimens are classified into symmetrical *c* and asymmetrical *a/b* elements. Slender cusp is erect to reclined with sharply edged anteroposterior margins. Base is expanded posteriorly. Upper margin of base particularly develops a winglike projection dwnwardly. *C* elements have two prominent sharply edged costae, which extend through lateral and posterolateral faces on both sides. Deep, longitudinal grooves occur between two costae on each surface. The grooves on one lateral face are shallower than those of the other face in *a/b* elements. Basal margin in aoral view is narrow and swells at two points aligned with costae.

Material examined.--Twenty four specimens; 6 *a/b* and 18 *c* elements (IGUT-ag1473, 1518, 1693, 2073, 2074).

Occurrence.--Beds ST-6 to 8 and 11 to 13 in the ST 1 section and beds LAN-34, 35, 37 to 39, 79, and 81 in the LAN 1 section.

Remarks.--The elements conform with descriptions by some recent authors (e.g., McCracken, 1989; Dzik, 1994). Characteristics of the specimens of this study are also similar to that of the ancestral species *P. varicostatus* (Sweet and Bergström, 1962), which has weaker development of anterobasal wings and antero-posterior asymmetry of transverse section than *P. liripipus*. McCracken (1989) and Dzik (1994) suggested that *P. liripipus* differs from *P. insculptus* because it lacks a denticle on the posterior part of base. The materials of this study are not elements of *P. insculptus* because all the specimens are adenticulate elements.

Protopanderodus varicostatus (Sweet and Bergström, 1962)

Plate 44: 10

Scolpodus varicostatus Sweet and Bergström, 1962, p. 1247, pl. 168, figs. 4-9, text-fig. 1:a, c, k.

Scandodus unistriatus Sweet and Bergström, 1962, p. 1245, pl. 168, fig. 12, text-fig. 1:e; Bradshaw, 1969, p. 1161, pl. 135, figs. 5, 6.

Protopanderodus varicostatus (Sweet and Bergström, 1962). Bauer, 1987, p. 27, pl. 3, figs. 19, 21-23; Dzik, 1994, p. 74, pl. 14, figs. 1-5, text-fig. 11:b; Albanesib, 1998, p. 130, pl. 16, figs. 21-22; Zhen, Percival, and Webby, 2003a, p. 157, 158, fig. 8: n-x.

Material examined.--Two specimen; 2 *b* element (IGUT-ag2061).

Occurrence.--Bed LAN-27 in the LAN 1 section and bed LAN-70 in the LAN 2 section.

Remarks.--Element is subsymmetrical form with deep lateral and posterolateral grooves on one lateral face. Lateral and posterolateral grooves on the other face are shallower. Therefore, these specimens are *b* element.

***Protopanderodus* sp. A**

Plate 49: 5

Material examined.--One specimen (IGUT-ag01442).

Occurrence.--Bed ST-5 in the ST 1 section.

Remarks.--Two furrows on each side are arranged asymmetrically, anterior margin is laterally compressed, and expanded base is similar to those of *P. varicostatus*. However, it is impossible to assign the specimen to a species because the specimen is broken and does not have basal margins.

Genus ***Protoprioniodus*** McTavish, 1973

Type species.--Protoprioniodus simplicissimus McTavish, 1973

Remarks.--I follow the concepts of this genus proposed by Sweet (1988) and Zhen et al. (2003b). Apparatus of *Protoprioniodus* species is a configuration of adenticulate ramiform and pectiniform elements.

Protoprioniodus yapu Cooper, 1981

Plate 42: 1-3, 5, 6

Oelandodus costatus van Wamel, 1974. An, Du, and Gao, 1985, pl. 6, fig. 21 (only).

Protoprioniodus yapu Cooper, 1981, p. 178, pl. 30, figs. 3-5, 8, 9, 11, 13; Zhen, Perval, and Webby, 2003b, p. 210, fig. 24: a-d.

Protoprioniodus aranda Cooper, 1981. Johnston and Barnes, 2000, p. 42, pl. 6, figs. 17, 22 (only).

Materials.--Twenty one specimens; 8 *b*, 6 *f*, and 7 *g* elements (IGUT-ag1820, 1821, 1824, 1832, 1835).

Occurrence.--Bed TUW-15 in the TUW 2 section.

Remarks.--Zhen et al. (2003b) divided Cooper's (1981) "*P*" elements into *f* and *g* elements. These two elements are recognized in the collection of this study. *F* element has cusp with a longitudinal costa on outer face, which extends to short outer lateral process. *G* element is also characterized by having a wider cusp and shorter posterior process with arched upper margin than those of *f* element. *B* element is strongly compressed laterally. Cusp inclines inwardly and bears inner mid costa. Long, slender posterior process and short anterior process are adenticulated. The *b* element is identical to asymmetrical "*S*" element of Cooper (1981). Symmetrical *c* element and *e* elements are not included in the collection of this study.

Genus ***Pseudooneotodus*** Drygant, 1974

Type species.--Oneotodus (?) *beckmanni* Bischoff and Sannemann, 1958

Pseudooneotodus beckmanni (Bischoff and Sannemann, 1958)

Plate 53: 6, 7

Oneotodus? beckmanni Bischoff and Sannemann, 1958, p. 98, pl. 15, figs. 22-25.

Pseudooneotodus beckmanni (Bischoff and Sannemann, 1958). Drygant, 1974, P. 67, pl. 2, figs. 34-39; Cooper, 1977, p. 1068, 1069, pl. 2, figs. 14, 17; Ross, Nowlan, and Harris, 1979, fig. 6: y; Nowlan and Barnes, 1981, p. 23, pl. 2, figs. 20, 21; McCracken and Barnes, 1981, p. 89, pl. 2, figs. 30, 31; Uyeno, 1990, p. 99, 100, pl. 1, figs. 36, 37.

Material examined.--One hundred and fifty three specimens; 153 squat elements (IGUT-ag2128, 2129).

Occurrence.--Beds ST-21 and 22 in the ST 2 section and beds LAN-60 to 62, 64, and 65 in the LAN 1 section.

Reamrks.--According to Barrick (1977), aparatus of this genus contains two types of elements, slender and squat forms. However, only squat element with single denticle occurs from the study section.

Pseudooneotodus **sp. A**

Plate 51: 13-15

Pseudooneotodus sp. Männik and Małkowski, 1998, pl. 1, fig. 8.

Material examined.--Six specimens; 1 slender and 5 squat elements (IGUT-ag2103 to 2105).

Occurrence.--Beds LAN-52, 53, and 55 in the LAN 1 section.

Remarks.--Three types of elements, slender coniform and two types of squat conical forms, are included in the collection of this study. Slender element and squat element with single denticle are similar to those of *Pseudooneotodus bicornis* Drygant, 1974. Latearlly compressed squat element is elliptical in cross-section. Top of element is slightly flattened and elliptical in oral view. Stratigraphic range of this species does not overlap that of *P. beckmanni* in the study setion.

Genus ***Pterospathodus*** Drygant, 1974

Type species.--Pterospathodus amorphognathoides Walliser, 1964.

Pterospathodus pennatus (Walliser, 1964)

Pterospathodus pennatus proceus (Walliser, 1964)

Plate 50: 1-15

Carniodus sp. B. Igo and Koike, 1968, p. 8, pl. 3, fig. 20.

Neoprioniodus costatus paucidentatus Walliser, 1964. Igo and Koike, 1968, p. 12, pl. 3, figs. 16, 17.

Neoprioniodus triangularis tenuirameus Walliser, 1964. Igo and Koike, 1968, p. 13, pl. 3, figs. 18, 19.

Pterospathodus pennatus proceus (Walliser, 1964). Barrick and Klapper, 1976, p. 86, pl. 1, fig. 19; McCraken, 1991, p. 109, pl. 4, figs. 12-23; Männik and Małkowski, 1998, pl. 1, figs. 6, 7, 11-13, 18; Männik, 1998, p. 1037, 1040, pl. 6, figs. 1-25, 27-35, text-fig. 16.

Spathognathodus pennatus proceus Walliser, 1964, p. 80, pl. 15, figs. 2-8; Igo and Koike, 1968, p. 18-19, pl. 2, figs. 8-10 (only).

Material examined.--Fifty six specimens; 26 *Pa*, 8 *Pb1*, 7 *Pb2*, 8 *M1*, 3 *Sb1*, 3 *Sc1*, and 1 *cfa* elements (IGUT-ag2075 to 2090).

Occurrence.--Beds LAN-49 and 50 in the LAN 1 section.

Remarks.--Männik (1998) described 21 types of elements as apparatus of this genus. I follow the locational notation of Männik (1998) here, because these elements are not able to be represented by the notation of Barnes et al. (1979). *Pa*, *Pb1*, *Pb2*, *M1*, *cfa*, *Sb2*, and *Sc2* elements are included in the collection of this study. However, it is impossible to discuss the apparatus composition of this species, because these specimens occur from only two samples and each form is representated by less than 10 specimens, except for *Pa* element. Walliser (1964) described *Pa* and *Pb* elements of three subspecies of *Pterospathodus pennatus*. According to him, *Pa* element of *P. pennatus proceus* has basal groove, extending posteriorly, and nearly straight lateral process. This element is similar to that of *P. pennatus pennatus* (Walliser, 1964), but *Pa* element of *P. pennatus pennatus* is characterized by shorter basal groove and higher denticles than that of *P. pennatus proceus*. The element of this study conforms with diagnosis of *P. pennatus proceus*.

Genus ***Rossodus*** Repetski and Ethington, 1983

Type species.--Rossodus manitouensis Repetski and Ethington, 1983

Remarks.--Apparatus of this genus consists of following four types of elements; acontiodiform *a* element, drepanodiform *b* element, suberect and symmetrical *c* element, and oistodiform or scandodiform *e* element (Ji and Barnes, 1994).

Rossodus manitouensis Repetski and Ethington, 1983

Plate 37: 7, 8, 10, 11

Rossodus manitouensis Repetski and Ethington, 1983, p. 289-301, figs. 1-5; Landing, Barnes, and Stevens, 1986, p. 1940, pl. 2, figs. 10, 11, 14, 18; Ethington et al., 1987, pl. 8-1, fig. 14; Repetski, 1988, figs. 2: r-v; Ji and Barnes, 1994, p. 56, pl. 17, figs. 1-9; Seo, Lee, and Ethington, 1994, fig. 7: 23-29.

Description.--A element has proclined to erect cusp and mid carina on anterior face. Posterior face gently concave. Base is small and expanded antero-posteriorly, and especially projects posteriorly. Lateral margins are keeled. Latearlly compressed *b* element has proclined cusp and anterior and posterior keels. Outer lateral face bears carina and inner lateral face is gently concave. Anterolateral and posterolateral faces of base are strongly compressed. Basal cavity is shallow and laterally expanded.

Material examined.--Eight specimens; 5 *a* and 3 *b* elements (IGUT-ag1978 to 1981).

Occurrence.--Beds TAR-16, 17, 20, and 21 in the TAR 2 section.

Remarks.-- Symmetrical *c* element and oistodiform *e* element do not occur from the study areas. Te *a* and *b* elements correspond to the coniform element described by Repetski and Ethington (1983).

Genus *Scabbardella* Orchard, 1980

Type species.--Drepanodus altipes Henningsmoen, 1948.

Remarks.--Apparatus of this genus consists of drepanodontiform, acodontiform, and distacodontiform morphotypes (Orchard, 1980). *Scabbardella* is similar to *Dapsilodus*, but *Dapsilodus* does not contain drepanodontiform elements and differs in the ratio of each morphotype (Orchard, 1980).

Scabbardella altipes (Henningsmoen, 1948)

Plate 47: 4, 8-10, 12-17

Drepanodus altipes n. sp. Henningsmoen, 1948, p. 420, pl. 25, fig. 14; Rhodes, 1955, 125, 126, pl. 10, figs. 6, 8, 29; Igo and Koike, 1967, p. 17, 18, pl. 2, fig. 8, text-fig. 4: m.

Drepanodus? altipes Hennigsmoen, 1948. Bergström, 1964, p. 22, 23, text-figs. 8, 9.

Acodus similaris Rhodes, 1955. Bergström, 1964, p. 8, 9, text-fig. 1; Hamar, 1966, p. 48-50, pl. 2, figs. 3-9, 13, text-fig. 4, nos. 5-10, 12; Igo and Koike, 1967, p. 13, 14, pl. I, figs. 16-18, text-fig. 4: e; Serpagli, 1967, p. 14-16, pl. 7, figs. 1-10.

Panderodus (Dapsilodus) similaris (Rhodes, 1955). Dzik, 1976, p. 435, text-fig. 15: c, d, k-m.

Scabbardella altipes (Henningsmoen, 1948). Orchard, 1980, p. 25, 26, pl. 5, figs. 2-5, 7, 8, 12, 20, 23, 24, 28, 30, 33, 35, text-fig. 4: c; Dzik, 1994, p. 64, 66, pl. 11, figs. 36-39, text-fig. 6: e; Wang, Bergström, and Lane, 1996, pl. 1, fig. 18; Ferretti and Barnes, 1997, p. 34, pl. 1, figs. 17-22; Ferretti, 1998, pl. 2, figs. 10-12; Leslie, 2000, figs. 3-36, 3-37; Sweet, 2000, figs. 9-14, 9-15; Wang and Qi, 2001, pl. 1, fig. 3; Agematsu, Sashida, Salyapongse, and Sardsud, in press C.

Description.--Two morphotypes, acodontiform *t* and drepanodontiform *s* elements, are recognized. *T* elements are of two types, long and short units. The long form has proclined to recurved cusp and extended, relatively long base. Depth of basal cavity varies, but it is approximately twice width of basal margin. Upper part of cusp is straight and tapers gradually, and terminates with anteriorly deflected posterior margin. Unit generally bears prominent groove on one side, which notches basal margin in some specimens and is gradually turned posteriorly on middle of cusp. Anteroposterior margin is sharply keeled. Base is laterally compressed and has usually straight or concave oral margin in lateral view. Outline of basal margin in aboral view is elliptical with lateral expansion between grooved position and anterior end. Generally, anterior edge is sharp and posterior edge is blunt. Latter element type has a short, abruptly expanded base. Upper margin of base is almost same length to basal margin in lateral view. Lateral surface of one side is smooth and broadly convex, while other side is ornamented by a sharp wedgelike posterolateral groove extending from base to near tip.

S element is typically erect with maximum curvature at approximately three-fifths length of unit from basal margin. Cusp is straight to anteriorly deflected and its cross section is almost circular. Anteroposterior margins are keeled from middle of cusp to basal margin and compression is strongest at lower part of base. Lateral surface of base is gently convex. Basal margin is generally teardrop-shaped, in oral view, with sharply edged posterior end, anterolateral convexities, and pointed anterior end; however, several specimens have asymmetrical bulges on each side.

Material examined.--Three hundred and ninety seven specimens; 282 *t* and 115 *s* elements (IGUT-ag1475, 1495, 1500, 1544, 1682, 1703, 1723, 1737, 1748, 1763,).

Occurrence.--Beds ST-4 to 18 in the ST 1 section and beds LAN-27 to 31, 33 to 39, 43, 79, and 80 in the LAN 1 section.

Remarks.--Although Orchard (1980) recognized six morphotypes, drepanodontiform, acodontiform, and distacodontiform elements, only the two types are identified in this study. Acodontiform elements are considered indicative of a curvature-transition series.

Scabbardella sp. cf. _S. altipes_ (Henningsmoen, 1948)

Plate 49: 4

Material examined.--One specimen (IGUT-ag1663).

Occurrence.--Bed ST-10 in the ST 1 section.

Remarks.--Specimen has laterally compressed anteroposterior margins and an expanded base. These characteristics are similar to the laterally compressed bicostate element of *S. altipes*. However, in several other respects, such as an asymmetric transverse section of base and obscure costa on lateral surface, these are discordant with *S. altipes*.

Genus ***Scandodus*** Lindström, 1955

Type species.--Scandodus furnishi Lindström, 1955

Scandodus sp. cf. _S. furnishi_ Lindström, 1955

Plate 37: 14, 15

Scandodus furnishi Lindström, 1955. Seo, Lee, and Ethington, 1994, fig. 10-18, 10-24.

Description.--Sscandodiform element is erect and slender unit. Laterally compressed cusp is strongly bent inwardly with keeled anterior and posterior margins. Lateral faces bear mid carinas. Base is short and expanded inwardly. Anterior marign of base is strongly compressed and slightly curves to form an angle 90° with basal margin. Basal cavity is shallow and tips toward anterior margin.

Material examined.--Ten specimens; 10 scandodiform elements (IGUT-ag1984, 1985).

Occurrence.--Bed TAR-36 in the TAR 2 section.

Remarks.--Lindström (1955) firstly described a scandodiform element as a form species *Scandodus furnishi*. This species has been redefined by Lindström (1971) as a multielement species containing scandodiform and drepanodiform elements in its apparatus. Johnston and Barnes (2000) suggested an apparatus of this species consisting of suberectiform *p* element, scandodiform or drepanodiform *q* element, and oistodiform *r* element. Although the specimens in the collection of this study resemble scandodiform element of this apparatus, those specimens differ from elements of *S. furnishi* in having strongly inclined cusp inwardly and base with rounded anterior margin.

Genus ***Scolopodus*** Pander, 1856

Type species.--*Scolopodus sublaevis* Pander, 1856

Scolopodus multicostatus Barnes and Tuke, 1970

Plate 44: 8, 9

Scolopodus multicostatus Barnes and Tuke, 1970, p. 92, pl. 18, figs. 5, 9, 15, 16, text-fig. 6: d; Ethington and Clark, 1982, p. 101, pl. 11, figs. 19, 20; Stait and Druce, 1993, p. 310, figs. 13: h-i, 19: f-j, l; Zhen, Percival, and Webby, 2003c. p. 212, fig. 6: a-r.

Description.--Element has erect cusp and short base. Posterior margin is sharply edged. One lateral face bears keeled anterolateral and posterolatearl costae. Several short, low costae are situated between the long costae. The other lateral face is smoothly rounded with a low costa along posterior margin. Aboral outline of basal margin is circular to ellipse.

Material examined.--Ten specimens; 10 *f/g* elements (IGUT-ag2059, 2060).

Occurrence.--Bed LAN-5 in the LAN 1 section and bed LAN-77 in the LAN 2 section.

Remarks.--According to Zhen et al. (2003c), apparatus of this species is seximembrate with *a*, *b*, *c*, *d*, *f*, and *g* elements. Scandodiform element, included in the collection of this study, is correlated with *f* or *g* elements of Zhen et al. (2003c), but these elements are gradually changed in shape. The specimens of this study are discriminated by having less vague costae from *Scolopodus quadratus*.

Scolopodus quadratus Pander, 1856

Plate 43: 14, 16-19

Scolopodus quadratus Pander, 1856, p. 26, pl. 2, fig. 6; Fåhræus, 1982, p. 21, pl. 2, figs. 1-14, pl. 3, figs. 1-8, 15; Zhen, Percival, and Webby, 2003b. p. 58, 59, pl. 5, figs. 15-21.

Scolopodus costatus Pander, 1856, p. 26, pl. 2, fig. 7.

Scolopodus striatus Pander, 1856, p. 26, pl. 2, fig. 8.

Scolopodus rex Lindström, 1955, p. 595, 596, pl. 3, fig. 32; Serpagli, 1974, p. 86, pl. 17, figs. 1-3, pl. 28, fig. 10; Landing, 1976, p. 640, pl. 4, fig. 14; Löfgren, 1978, p. 109, pl. 1, figs. 38, 39; Repetski, 1982, p. 50, pl. 23, fig. 6; Stouge and Bagnoli, 1988, p. 25, pl. 9, figs. 1-6; Wang, Bergström, and, Lane, 1996, pl. 2, figs, 18, 19; Albanesi, 1998b, p. 133, pl. 12, figs. 14-17.

Description.--A element is subsymmetrical form and slightly compressed laterally with keeled posterior margin. One to six keeled costae are situated on each lateral face. Subsymmetrical *b* element bears 2 to 3 costae with sharp edges on each lateral face. Basal margin is circular to elliptical in aboral view. *C* element is symmetrical form with 3 to 9 costae on each lateral faces. Aboral outline of basal margin is circular to elliptical. Asymmetrical *g* element has sharply edged posterior margin. One lateral face bears 3 to 5 keeled lateral costae. The other face is smoothly rounded.

Material examined.--Sixteen specimens; 5 *a*, 2 *b*, 6 *c*, and 3 *g* elements (IGUT-ag2046 to 2050).

Occurrence.--Bbeds LAN-8 and 10 in the LAN 1 section, and beds LAN-75 to 77 in the LAN 2 section.

Remarks.--I follow the definition of this species described by Zhen et al. (2003b, 2003c). The *a*, *b*, and *c* elements from the collection of this study form a symmetry transition series as well as those of Zhen et al. (2003b, 2003c). The specimens of this study are highly various in number of costae, symmetry and curvature of cusp, and degree of lateral compression.

Scolopodus transitans Druce and Jones, 1971

Plate 34: 1, 2

Scolopodus transitans Druce and Jones, 1971, p. 95, pl. 15, figs. 10-15, text-fig. 30: g, h; Jones, 1971, p.

68, pl. 6, figs, 8-11, pl. 9, fig. 6.

Material examined.--Three specimens; 3 nongeniculate elements (IGUT-ag1933, 1934).

Occurrence.--Beds TAR-3 and 4 in the TAR 1 section.

Remarks.--Elements described by Jones (1971) have relatively long and slender cusp. Specimens occur from the study section have various length of cusp and degree of expansion of base.

Scolopodus sp. A

Plate 39: 7-17

Description.--Element has proclined to erect cusp and long base. Conspicuous, coarse striations cover most of the surface of unit, from above basal margin to tip of cusp. *A/b*, *c*, *d*, and *e* elements are recognized. *A/b* element is subsymmetrical to asymmetrical and laterally compressed. One lateral face bears longitudinal groove. Anterior face is broadly rounded, and posterior face is gently convex to flattened. Acostate *c* element is symmetrical form with circular cross-section throughout the element. Symmetrical *d* element is laterally compressed and has erect cusp. Longitudinal grooves are developed from above basal margin to tip of cusp on lateral faces. Anterior face is broadly rounded, and posterior face is convex to flattened. *E* element is asymmetrical and acostate form with proclined cusp and twisted base. Cusp has rounded anterior face and keeled posterior margin, and is drop-shaped in cross-section. Base is circular in aboral view. *A/b*, *c*, and *d* elements form a symmetry transition series.

Material examined.--Twenty two specimens; 4 *a-b*, 8 *c*, 8 *d*, and 2 *e* elements (IGUT-ag2009 to 2018).

Occurrence.--Beds TAR-46 to 48 in the TAR 2 section.

Remarks.--The specimens of this study are similar to those of *Parapanderodus* Stouge, 1984 and *Striatodontus* Ji and Barnes, 1994 in having coarse, longitudinal striations. However, the specimens of this study do not bear median groove on posterior face, which is significance characteristics for definition of *Parapanderodus* and *Striatodontus*. Therefore, I temporaly describe this species as *Scolopodus*.

Scolopodus sp. B

Plate 42: 16

Materials examined--One specimens; 1 nongeniculate element (IGUT-ag2036).

Occurrence.--Bed TUS-11 in the TUS section.

Remarks.-- Element has reclined cusp and short base with four sharp costae on each lateral face. Anterior and posterior margins are keeled. Outline of the basal margin is oval in aboral view. Keeled costae of the specimen suggests that this element is identified as species of *Scolopouds*.

***Scolopodus* sp. C**

Plate 39: 2

Materials examined --One specimens; 1 nongeniculate element (IGUT-ag2003).

Occurrence.--Bed TPP-11 in the TPP section.

Remarks.--Element has reclined, slender cusp and flared base. Cusp twists inwardly. Deep, longitudinal fine costae are developed on surface of entire element. Anterior and posterior margins are norrowly rounded and broadly convex, respectively. Longitudinal depressions are located on lateral faces from above basal margin to tip of cusp. The numerous fine costae on surface and flare-like base characterize this species.

Genus ***Teridontus*** Miller, 1980

Type species.--*Oneotodus nakamurai* Nogami, 1967.

Teridontus nakamurai (Nogami, 1967)

Plate 34: 14-16

Oneotodus nakaurai Nogami, 1967, p. 216, 217, pl. 1, figs. 9, 12, test-fig. 3:a, b.

Teridontus nakamurai (Nogami, 1967). Miller, 1980, p. 34, 35, pl. 2, figs. 15, 16, test-fig. 40; Landing and Barnes, 1981, p. 1614, pl. 1, figs. 15-17, 20, text-fig. 3: 16; Nowlan, 1985, p. 116, fig. 5: 26-32, pl. 1, figs. 1-3, 5; Ji and Barnes, 1994, p. 64, 65, pl. 24, figs. 1-9, text-fig. 37: c; Landing, Westrop, and Hernick, 2003, fig. 7: 3

Materials.--Thirty one specimens; 31 *a/b* elements (IGUT-ag1946 to 1948).

Occurrence.--Beds TAR-3 to 5, 6, 8, and 11 to 14 in the TAR 1 section and beds TAR-16, 17, 20 to 22, 27, 31, and 33 in the TAR 2 section.

Remarks.--Simple coniform element is erect to reclined and nearly circular in cross-section. These elements confrom with a/b element of Ji and Barnes (1994).

Genus ***Triangulodus*** van Wamel, 1974

Type species.--Paltodus volchovensis Sergeeva, 1963

Triangulodus brevibasis (Sergeeva, 1963)

Plate 40: 18, 19

Scandodus brevibasis (Sergeeva, 1963). Lindström, 1971, p. 39, pl. 1, figs. 24-27, text-fig. 3; Serpagli, 1974, p. 82, 83, pl. 18, figs. 5-7, Pl. 27, figs. 2-3, text-fig. 21.

Description.--Element is slender and twists. Cusp is proclined. Anterolateral faces bear keel-like costae running through the unit, but they do not reach basal margin. Anterior surface is slightly rounded to flattened, and posterior margin is edged. Basal margin is triangular in aboral view.

Materials.--Four specimens; 4 trichonodelliform elements (IGUT-ag2034, 2035).

Occurrence.--Beds TPP-24, 27, and 28 in the TPP section.

Remarks.--Serpagli (1974) described three types of elements as apparatus of this species, drepanodiform, trichonodelliform (acodiform), and destacodiform elements. The specimen of this study coincides with his trichonodelliform elements.

Triangulodus larapintinensis (Crespin, 1943)

Plate 41: 18-20

Oistodus larapintinensis Crespin, 1943, p. 231, pl. 31, figs. i-6, 9, 12, 13.

Triangulodus larapintinensis (Crespin, 1943). Stait and Druce, 1993, p. 315, 317, figs. 14: a-c, 21: d-f, h-j; Zhen, Percival, and Webby, 2003b, p. 212-216, fig. 28: a-v.

Trigonodus larapintinensis (Crespin, 1943). Cooper, 1981, p. 180, pl. 27, figs. 5, 6, 11 ,12 ,16, 17; Watson, 1988, p. 129, pl. 2, figs. 12-14, 18-20, 22, 23.

Description.--I follow the apparatus reconstruction of Zhen et al. (2003b). Collection of this study yields *a*, *c*, *e*, and *f* elements. Asymmetrical *a* element is characterized by strongly asymmetrical cusp with keeled anterior and posterior margins. *C* element is symmetrical and reclined form with one posterior and two lateral costae. *F* element has erect cusp, which slightly curves and twists inwardly. *E* element is recurved oistodontiform.

Materials.--Ten specimens; 2 *a*, 1 *c*, 1 *e*, and 6 *f* elements (IGUT-ag1810, 1812, 1813).

Occurrence.--Bed TPP-28 in the TPP section, beds TUW13 and 14 in the TUW 2 section, beds LAN-5 and 8 in the LAN 1 section, and bed LAN-76 in the LAN 2 section.

Remarks.--The elements from the study sections fully conform with description of Zhen et al. (2003b).

Genus ***Variabiloconus*** Landing, Barnes, and Stevens, 1986

Type species.--Paltodus bassleri Furnish, 1938.

Variabiloconus bassleri (Furnish, 1938)

Plate 34: 3-5, 8-10

Paltodus bassleri Furnish, 1938, p. 331, pl. 42, figs. 1, 9, 10; Ethington and Clark, 1971, p. 72, pl. 2, figs. 2, 4, 6.

Utahconus? *bassleri* (Furnish, 1938). Landing and Barnes, 1981, p. 1622, 1624, pl. 1, fig. 19.

Variabiloconus bassleri (Furnish, 1938). Landing, Barnes, and Stevens, 1986, p. 1944, pl.1 3, fig. 7; Ji and Barnes, 1994, p. 67, 68, pl. 25, figs. 14-26, text-fig. 38: d; Landing, Westrop, and Hernick, 2003, fig. 8: 2-5.

Materials.--Seventy two specimens; 48 *a*, 19 *b*, and 5 *c* elements (IGUT-ag1935 to 1940).

Occurrence.--Beds TAR-3 to 14 in the TAR 1 section and beds TAR-16 to 18, 22, 23, 27, 29, and 36 in the TAR 2 section.

Remarks.--According to Ji and Barnes (1994), apparatus of this species is quadrimembrate consisting *a*, *b*, *c*, and *e* elements. The specimens of this study are simple coniform elements with proclined to erect cusp and assigned to *a*, *b*, and *c* elements. *A* and *b* elements form a symmetry transition series.

Genus **Unknown**

Gen. et sp. indet. 1

Plate 38: 14

Material examined.--One specimen (IGUT-ag1999).

Occurrence.--Bed TAR-23 in the TAR 2 section.

Remarks.--Elements is asymmetrical and conical form, and characterized by markably keeled posterolateral costa on inner face. Cusp is proclined and base is expanded antero-posteriorly. Anterior and posterior margins are laterally compressed and sharply edged. Outer lateral face is smoothly flattened. Anterobasal process downwardly projects.

Gen. et sp. indet. 2

Plate 38: 15

Material examined.--One specimen (IGUT-ag2000).

Occurrence.--Bed TAR-46 in the TAR 2 section.

Remarks.--Element is asymmetrical form having proclined cusp. Strongly compressed anterior and posterior margins bend inwardly. Both lateral faces bear conspicuously keeled costae. Upper margin of base is short and meets basal margin at 60°. Blade-like anterior process is adenticulate. The element is similar to Gen. et sp. Indet. 1. However, Gen. et sp. Indet. 2 has logitudinal costae on both lateral faces.

Gen. et sp. indet. 3

Plate 37: 6-8

Material examined.--Four specimens; 4 geniculate elements (IGUT-ag1992 to 1994).

Occurrence.--Beds TAR-41 and 42 in the TAR 2 section.

Remarks.--Element is oistodiform and laterally compressed. Anterior margin is rounded and posterior margin is sharply edged. Upper margin of base is arched and keeled. Posterobasal corner is narrowly rounded and anterobasal corner forms an angle of 45° . Outer and inner faces of base are flattened and swelled, respectively. Basal margin is rimmed by rounded ridge. Identification of the elements is difficult due to their poor preservation.

Gen. et sp. indet. 4

Plate 37: 2, 3, 6

Acodus sp. Seo, Lee, and Ethington , 1994, figs. 7-15, 7-16.

Material examined.--Four specimens; 4 nongeniculate elements (IGUT-ag1973 to 1975).

Occurrence.--Bed TAR-27 in the TAR 2 section.

Remarks.--Element is simple coniform and laterally compressed. Blade-like cusp is proclined with anterior and posterior margins, which are keeled and straight in lateral view. Outer face is flattened and inner face bears mid carina. Upper margin of short base is laterally compressed. Anterobasal blade extends downwardly. Basal cavity is small and inwardly expanded below the carina. Basal margin is straight in lateral view.

Acodus sp. described by Seo et al. (1994) resembles the elements of this study. Seo et al. (1994) assigned their element to *Acodus*. However, it is difficult to discuss the taxonomy because they did not give a description and the elements of this study are poorly preserved.

Gen. et sp. indet. 5

Plate 53: 12, 15

Material examined.--Six specimen; 6 geniculate element (IGUT-ag2136, 2137).

Occurrence.--Bed LAN-61 in the LAN 1 section.

Remarks.--Specimens are oistodiform element. Slender cusp is almost straight and slightly curves downwardly in distal part. Base has arched anterior and posterior margins and nearly straight basal margin in lateral view. Anteobasal and posterobasal corners form an angle of 60 to 80°. Aboral outline of basal margin is modified elliptical form with sharply pointed anterior and posterior ends. The preservation are not adequate for identification of species.

Gen. et sp. indet. 6

Plate 45: 18

Material examined.--One specimen; 1 geniculate element (IGUT-ag1438).

Occurrence.--Bed ST-4 in the ST 1 section.

Remarks.--Element is oistodiform with long, robust cusp and short base. Cusp slightly bends inwardly and has lenticular cross-section. Anterior margin forms 60° with basal margin. Basal cavity is narrow in oral view.

Gen. et sp. indet. 7

Plate 37: 3-5, 9

Material examined.--Twenty three specimens; 23 nongeniculate elements (IGUT-ag1988 to 1991).

Occurrence.--Beds TAR-38 to 42 in the TAR 2 section.

Remarks.--Element is simple cone with slender, proclined cusp and posteriorly expanded base. Anteiror margin is narrowly rounded. Posterior part of lateral faces is strongly compressed at cusp. Cross-section of cusp is drop-like form with posterior tip. Anterior margin of base meets basal margin at

90 to 120°. Posterobasal corner is an angle of 30 to 60°. Basal cavity is sharply pointed near anterior margin. Outline of basal margin is oval to drop-shape with posterior tip in aboral view.

Elements exhibit a high variation in degree of compression of cusp and in expansion of base. Most of specimens bilaterally are symmetrical form, but some are asymmetrical. The asymmetrical elements possess markably rounded costa along anterolateral face of inner side.

Gen. et sp. indet. 8

Plate 40: 6

Material examined.--Two specimen; 2 digyrate elements (IGUT-ag2024).

Occurrence.--Bed TPP-18 in the TPP section.

Remarks.-- Digyrate element is antero-posteriorly compressed with slender cusp and two lateral processes. Anterior face of element is flattened. Cusp is inclined inwardly and has rounded posterior carina. Keeled lateral costae of cusp extend to lateral processes, which downwardly elongate. Outer lateral process is adenticualte. Inner lateral process bear at least five denticles. Aboral side is entirely grooved, with prominent posterior expansion developed below cusp. Basal margins of these processes meet at about 60°.

Gen. et sp. indet. 9

Plate 37: 12, 13

Material examined.--Five specimens; 5 geniculate elements (IGUT-ag1982, 1983).

Occurrence.--Beds TAR-31 to 33 in the TAR 2 section.

Remarks.--Element is oistodiform with edged anterior and posterior margins. Outer face is gently convex and inner face has mid carina. Upper margin of short base is sharply edged. Anterobasal corner forms an acute angle. Basal margin is wavy in lateral view and elliptical with expansion in posterior part in aboral view. Identification of species is difficult due to their poor preservation.

Gen. et sp. indet. 10

Plate 49: 12

Drepanodus? sp. 5 Repetski, .1982, p. 24, pl. 8, fig. 2.

Material examined.--One specimens; 1 nongeniculate element (IGUT-ag2174).

Occurrence.--Bed TAR-42 in the TAR 2 section.

Remarks.--Element is coniform and laterally compressed with proclined cusp. Keeled anterior and posterior margins are developed into adenticulate anterior and posterior blade at base. Basal margin gently concave in lateral view. Aboral side is entirely grooved, with small and shallow basal cavity developed below cusp. The element is identified with *Drepanodus*? sp. 5 described by Repetski (1982). However, the preservation and number of the specimens of this study are not adequate for identification of species.

Gen. et sp. indet. 11

Plate 37: 4, 5

Material examined.--Two specimens (IGUT-ag1976, 1977).

Occurrence.--Beds TAR-26 and 23 in the TAR 2 section.

Remarks.--Unit is slender, simple cone element and has proclined cusp. Inner lateral face is flattened at cusp. Mid carina is developed on outer lateral face. Anterior margin is narrowly rounded distally and broadly convex in basal part. Posterior margin of cusp is sharply edged. Base is short and unexpanded. Basal cavity is pointed toward anterior margin. Outline of basal margin is circular to oval with narrow posterior end.

Gen. et sp. indet. 12

Plate 45: 16, 17

Material examined.--Five specimens (IGUT-ag2069, 2070).

Occurrence.--Beds LAN-31 to 33 in the LAN 1 section.

Remarks.--Element is simple coniform and has erect to reclined cusp with sharply edged anterior and posterior margins. Both lateral faces bear carinae. Base is slightly flared. Anterior part of base is strongly compressed laterally and anterobasal corner slightly warps outwardly. Basal margin is straight in lateral view and elliptical with sharp projection at posterior end in aboral view. The anterior compression of base characterizes this species.

The elements are similar to *q* element of *Drepanodus* species. However, the element of this study is characterized by more remarkable anterior compression and broadly rounded posterior margin at base than those of *Drepanodus* species.

Gen. et sp. indet. 13

Plate 44: 15, 16

Material examined.--Six specimens; 6 geniculate elements (IGUT-ag2171, 2172).

Occurrence.--Beds LAN-5, 7, and 8 in the LAN 1 section.

Remarks.--Geniculate element has slender cusp, which is inclined inwardly and tapers distally. Anterior and posterior margins are sharply keeled. Outer lateral face is gently convex and inner lateral face is concave, except for rounded carina. Short base is expanded bilaterally. Elongated anterobasal blade bears 1 to 3 denticles.

Gen. et sp. indet. 14

Plate 40: 4

Material examined.--One specimen; 1 nongeniculate element (IGUT-ag2022).

Occurrence.--Bed TPP-18 in the TPP section.

Remarks.--Element is characterized by conspicuously wide, thin lateral costae. Anterior and posterior faces are flattened and rounded, respectively. Base is expanded posteriorly with shallow basal cavity. These characteristics may correspond to diagnosis of *Juanognarhus*. However, it is difficult to discuss taxonomy of the element due to its poor preservation.

Gen. et sp. indet. 15

Plate 45: 14

Material examined.--One specimen; 1 nongeniculate element (IGUT-ag1437).

Occurrence.--Bed ST-4 in the ST 1 section.

Remarks.--Unit is nongeniculate and erect with thin cusp and wide base. Anterior and posterior margins are laterally compressed. Base is expanded posteriorly from a point of maximum curvature. Upper margin of base forms an angle of 45° with basal margin. Longitudinal furrow runs along posterolateral surface of inner side. Outer lateral face is convex at base.

Gen. et sp. indet. 16

Plate 40: 5

Material examined.--Four specimen; 4 nongeniculate element (IGUT-ag2023).

Occurrence.--Beds TPP-17 and 18 in the TPP section.

Remarks.--Unit is laterally compressed coniform with proclined, straight cusp and small base. The elements are slightly similar to Gen. et sp. Indet. 4, but their poor preservation is not adequate for discussion of taxonomy.

Gen. et sp. indet. 17

Plate 36: 15

Material examined.--One specimen; 1 geniculate element (IGUT-ag1971).

Occurrence.--Bed TAR-46 in the TAR 2 section.

Remarks.--Element is laterally compressed with elongate cusp. One lateral face is flattened and the other face bears low carina. Short upper margin of base, which is arched and markably keeled, meet basal margin at about 80°. Anterior margin of base is narrowly rounded and form right angles with basal margin.

Gen. et sp. indet. 18

Plate 36: 13, 14

Material examined.--Two specimen; 2 geniculate element (IGUT-ag1969, 1970).

Occurrence.--Bed TAR-46 in the TAR 2 section.

Remarks.--Element is distinguished from other oistodiform element in this study by its stout unit and basal margin rimmed by rounded ridge. Cusp has mid carina on outer lateral face. Upper margin of base is short and keeled. Anterior margin is narrowly rounded throughout element and smoothly arched in lateral view.

Gen. et sp. indet. 19

Plate 38: 13

Material examined.--One specimen; 1 geniculate element (IGUT-ag1998).

Occurrence.--Bed TAR-18 in the TAR 2 section.

Remarks.--Element is characterized by inwardly twisted base and broadly rounded outer lateral face. Inner face of cusp is concave, except for mid carina. Basal margin is expanded inwardly and its anterior and posterior ends sharply pointed in aboral view.

Gen. et sp. indet. 20

Plate 49: 1, 2

Material examined.--Four specimen; 4 geniculate element (IGUT-ag2071, 2072).

Occurrence.--Beds LAN-33 and 34 in the LAN 1 section.

Remarks.--Oistodiform element has slender cusp with sharply edged anterior and posterior margins.

Base is extended posteriorly. Straight posterior margin of cusp form about 60° with upper margin of base. Anterior margin is sharply bent downwardly with an angle of 40 ° at one-third length from basal margin. Basal margin sharply turns up with about 40° at one-half length in lateral view. Anterobasal and posterobasal corners are pointed at 60 to 80° and 30 to 45 °, respectively. Basal cavity is slightly expanded bilaterally and tips toward anterior margin in aboral view.

The elements are discriminated from other geniculate elements of this study by having high base, whose outline is triangular or lozenge in lateral view.

Gen. et sp. indet. 21

Plate 43: 15

Material examined.--Three specimen; 3 geniculate element (IGUT-ag2051).

Occurrence.--Beds LAN-76 and 77 in the LAN 2 section.

Remarks.--Specimen is oistodiform element with inwardly inclined cusp and short base. Anterior and posterior margins are narrowly rounded. Outer face is broadly convex and inner face bears mid costa. Base has short posteobasal bar. Basal cavity is slightly expanded laterally. The elements are characterized by rounded unit with smoothly curved anterobasal and posterobasal corners.

Gen. et sp. indet. 22

Plate 55: 10-12

Description.--Element is laterally compressed ramiform unit with finely denticulate anterior and posterior processes. The denticles are basally fused and distally discrete. Surface of element is ornamented by infinite fine pits. Basal margins of processes are entirely grooved, with slightly lateral expansion developed below main cusp. The elements are divided into two types, A and B. Type A has high, proclined cusp and relatively short anterior and posterior processes. Outer lateral face is broadly convex. Basal margins of anterior and posterior processes form an angle of 30 to 45° in lateral view. Type B is characterized by having recurved cusp and long anterior and posterior processes. Anterior denticles are higher than posterior ones. Anterior and posterior processes inwardly inclined distally.

Material examined.--Sixteen specimens; 14 type A and 2 type B element (IGUT-ag2161 to 2163).

Occurrence.--Beds LAN-65 in the LAN 1 section.

Remarks.--Although the elements of type B resemble form species *Dinodus leptus* Cooer, 1939, it seems that Cooper's (1939) specimens possess more robust denticles than those of the specimens of this study. Dzik (1997, fig. 26) illustrated several sketches of *a* and *b* elements of *Dinodus* sp., which is similar to the elements of type A and B of this study. However, it is difficult to discuss their taxonomy in detail, because Dzik (1997) did not describe the *a* and *b* elements of *Dinodus* sp. Cooper (1939) and Dzik (1997) reported their specimens from the Mississippian sequences. However, the elements of this study co-occur with *Flajsella stygia* and *Flajsella sigmostygia*, which are typical species of Early Devonian.

SYSTEMATIC PALEONTOLOGY

GRAPTOLITES

All specimens described in this paper are deposited in the Institute of Geoscience, University of Tsukuba, with the prefix IGUT.

Faimly **Normalograptidae** Štorch and Serpagli, 1993

Genus ***Normalograptus*** Legrand, 1987

Type species.--*Normalograptus normalis* (Lapworth, 1877)

Diagnosis.--*Normalograptus* species have astogenitic pattern H (Melchin, 1998) and climacograptid to glyptograptid thecae, which are rounded and alternating. Median septum is straight. $Th2^1$ or some later theca are dicalycal.

Normalograptus pseudovenustus pseudovenustus (Legrand, 1986)

Plate 32: 1-10

Climacograptus venustus venustus Legrand, 1976, p. 158-162, fig. 3A-3E.

?*Climacograptus venustus venustus* Legrand, 1976, p. 160, 161, fig. 4A.

Climacograptus pseudovenustus (Legrand, 1976). Legrand, 1986, p. 197, fig. 2.

Description.--Rhabdosome, 18.8 mm in maximum length, has a long virgella and nema. Virgella mer is up to 10.9 mm and the latter attains 18.9 mm. Width is 0.5-1.0 mm at $th1^1$ ~$th1^2$ level, and reaching 1.3-2.2 mm in maximum between a half to two-thirds length from the sicula. Septum is almost straight. Gently sigmoid thecal wall are inclined proximally, and are vertical to weakly geniculate distally. The number of thecae is 10 to 15 in 10 mm proximally and 9.5 to 11 subsequently.

Material examined.--Thrity-two specimens (IGUT-ag0001 to 0007, 0009 to 0018, 0020, 0024 to 0026, 0028 to 0031, 0036 to 0038, 0043, 0044).

Occurrence.--Bed ST-g in the ST 1 section.

Remarks. Although the specimens of this study possess various sized rhabdosome, their morphological characteristics accord with the description of *Climacograptus* (*Cl.*) *venustus* Legrand, 1976. Among the *venustus* subspecies, whose name is transposed *pseudovenustus* by Legrand (1986), *Cl.* (*Cl.*) *venustus venustus* is distinguished from the other subspecies especially by a long virgella and measurements of morphology. The specimens described herein are somewhat smaller than the type of Legrand (1976), but any other measurements correspond with that of Legrand (1976). One of the *venustus* subspecies, *Cl.* (*Cl.*) *venustus venustulus*, is also smaller than *venustus venustus*. However, this subspecies has a rhabdosome whose width is nearly constant as a whole, and differs from the specimens of this study in this respect. Although some specimens have particularly short rhabdosomes, 4.7-6.1 mm in length (Plate32: 8, 10), I assign these specimens to *N. pseudovenustus pseudovenustus* because other characteristics such as a width of rabdosome, a number and shape of thecae, and a long virgella and nema agree with this species.

***Normalograptus* sp.**

Plate 32: 11

Description.--Rhabdsome, 10 mm in length, is 0.9 mm in width at $th1^1$ to $th1^2$ level and immediately reaches the maximum width, 1.3 mm. Thecae have vertical walls. Virgella is 1mm and nema is 8 mm in length.

Material examined.-- One specimen (IGUT-ag 0021).

Occurrence.--Bed ST-g in the ST 1 section.

Discussion.--This specimen is distinguished from the others by thecal form, which is climacograptid, and a short virgella. However, it is impossible to ditermine a species name because of small number of specimen and poor preservation.

SYSTEMATIC PALEONTOLOGY

TENTACULITES

All specimens described in this paper are deposited in the Institute of Geoscience, University of Tsukuba, with the prefix IGUT.

Order **Dacryconarida** Fisher, 1962

Family **Nowakiidae** Bouček and Prantl, 1960

Genus **Nowakia** Gürich, 1896

Type species.--*Tentaculites elegans* Barrande, 1852

Diagnosis.--Tube is straight, medium in size, and commonly 3 to 5 mm long, mainly with a conical shape that is often nearly cylindrical distally. Transverse rings are sharp, with various height and width. Longitudinal ribs are present. Inner side of wall reflects the outer relief. Drop-shaped initial chamber is differentiated from a tube. It ranged from Llandvery (Lower Silurian) to Frasnian (Upper Devonian) and is known worldwide (Churkin and Carter, 1970; Tunnicliff, 1983, 1989; Yochelson and Kirchgasser, 1986).

Nowakia acuaria (Richter, 1854)

Plate 33: 1-15

Tentaculites acuarius. Richter, 1854, p. 285, pl. 3, figs. 3-9.

Nowakia acuaria (Richter, 1854). Bouček, 1964, p. 60-69, pl. 1, figs. 1-7, pl. 3, figs. 1-6, pl. 4, figs. 1-4, text-figs. 10, 11, 13-17; Lardeux, 1969, p. 91-96, pl. 30, figs. 1-3, pl.31, figs. 1-8, pl. 32, figs. 1-4, text-figs. 64-66; Alberti, 1970, p. 391, 392; Churkin and Carter, 1970, p. 62, pl. 16, figs, 1-8; Agematsu, Sashida, Salyapongse, and Sardsud, in press B.

Description.--Tube is straight, conical, less than 3.3 mm in length, and gradually increases in width to 0.5 mm; angle of divergence is 10 to 15°. An initial chamber, which is differentiated from a tube, has a teardrop shape slightly pointed downward, 0.15 to 0.2 mm in length, 0.12 to 0.16 mm in diameter, and has distinct longitudinal ribs. Transverse rings with sharp crests are present on a tube, with highest density (10 to 17 per 0.5 mm) proximally, and lower density (10 per 0.5 mm) distally. Longitudinal ribs of the tube are weak.

Material examined.--Fifteen specimens (IGUT-ag0051 to 0065).

Occurrence.--Bed ST-t in the ST 2 section.

Remarks.--The specimens are smaller than those described by Churkin and Carter (1970), which are 7 mm in maximum length. Although the specimens indicate a high density of transverse rings proximally, *N. acuaria* shows a variety of density and ring spacing (Churkin and Carter, 1970). The initial chamber has several characteristics, which is similar to those *Nowakia barrandei* (Bouček and Prantl, 1959), and *N. cancellata* (Richter, 1854). However, the specimens differ from these two species in having no distinct longitudinal ribs, numerous transverse rings, and a distal, cone-shaped tube.

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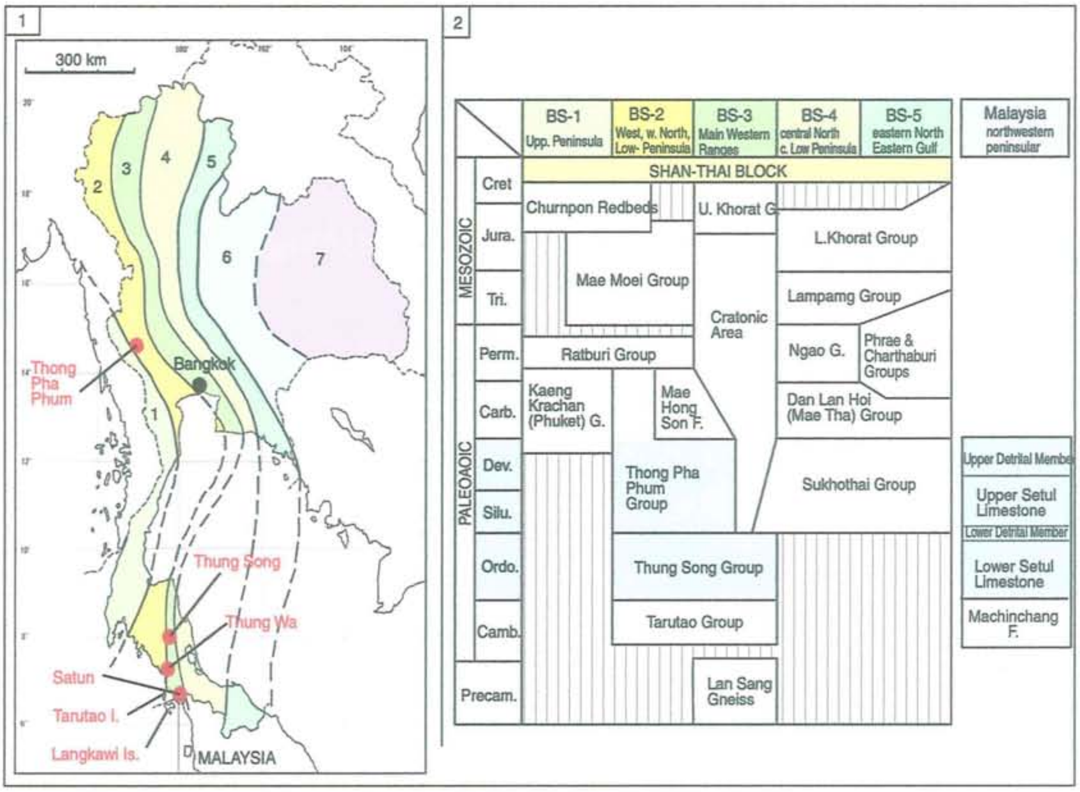

Figure 1. 1: Index map showing the study areas and the seven stratigraphic belts of Thailand
2: Generalized stratigraphic nomenclature of Paleozoic and Mesozoic in the BS-1 to BS-5 and the Lower to Middle Paleozoic in the northern peninsular Malaysia (After Bunopas, 1992; Cocks et al., 2005).

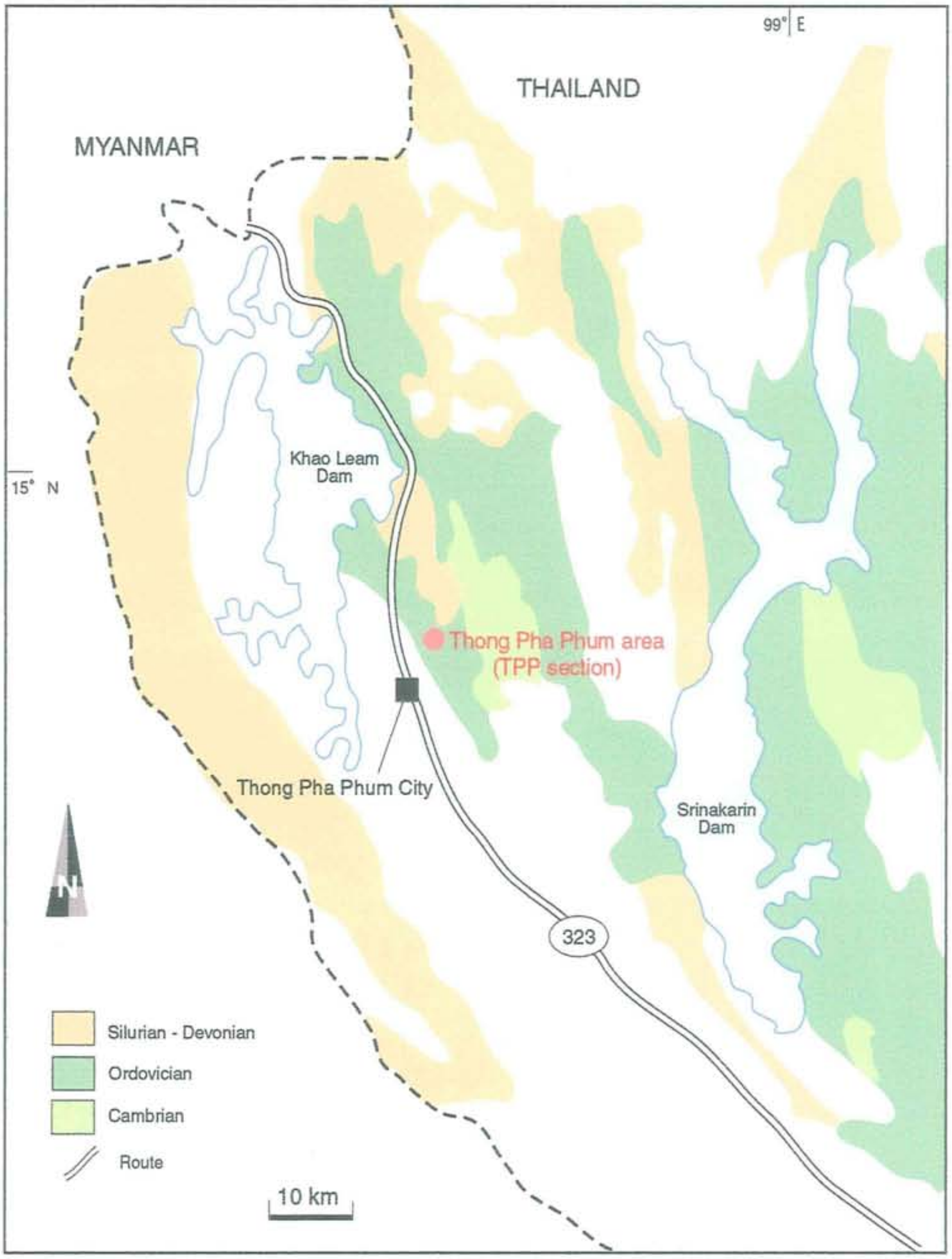

Figure 2. Simplified geologic map of the Thong Pha Phum area in western Thailand. Basic map is Geological Map of Thailand, scale 1:2,500,000 (Department of Mineral Resources of Thailand, 2000).

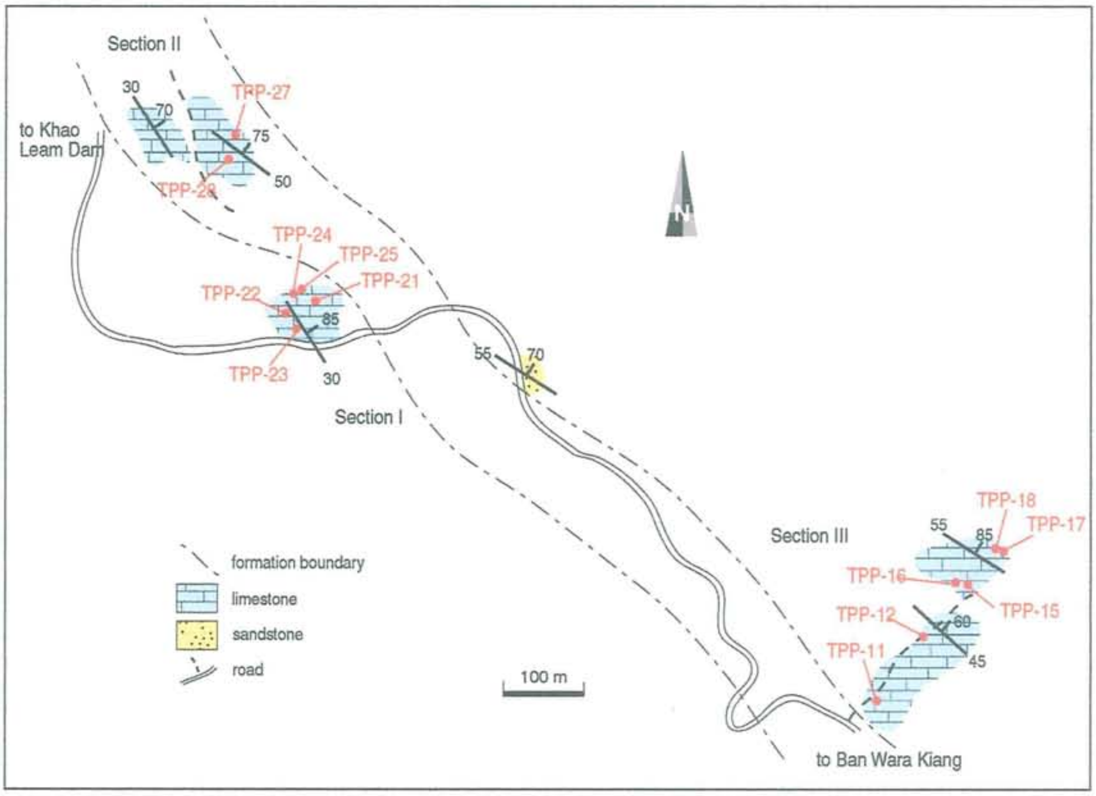

Figure 3. Route map showing the study sections and the distribution of sedimentary rocks in the Thong Pha Phum area.

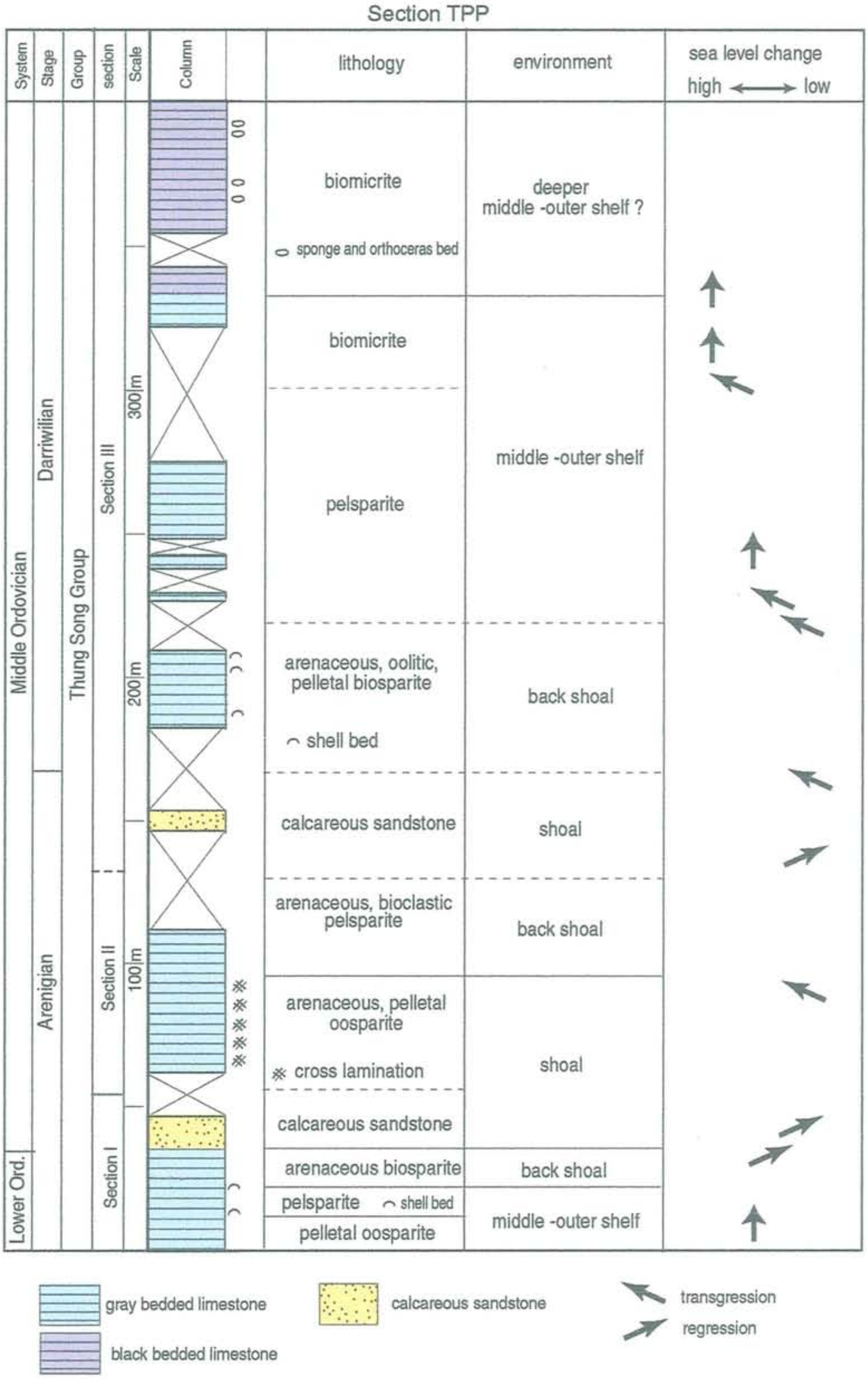

Figure 4. Lithologic column of the TPP section in the Thong Pha Phum area, and the reconstructed depositional environments and sea-level change.

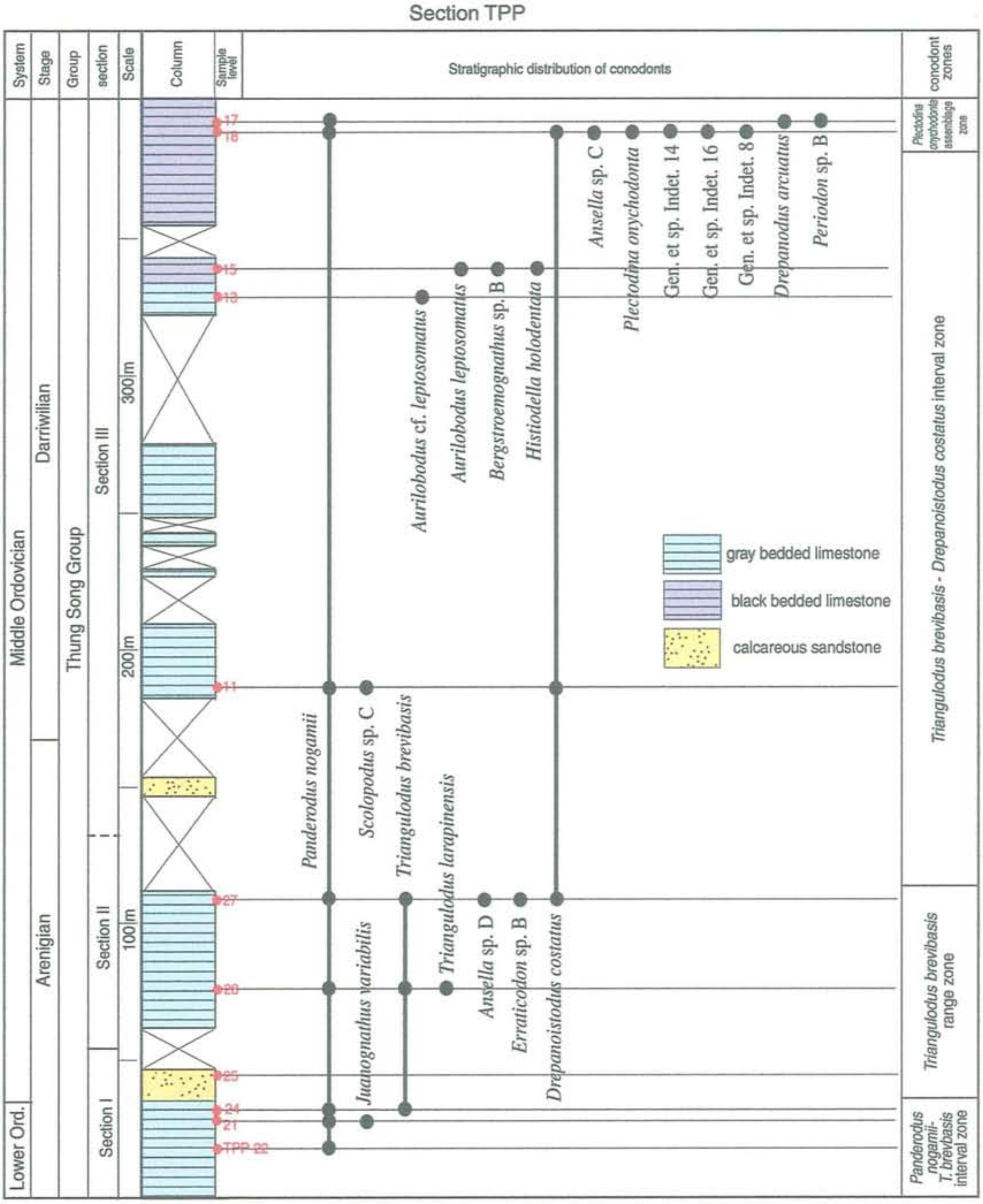

Figure 5. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the TPP section in the Thong Pha Phum area.

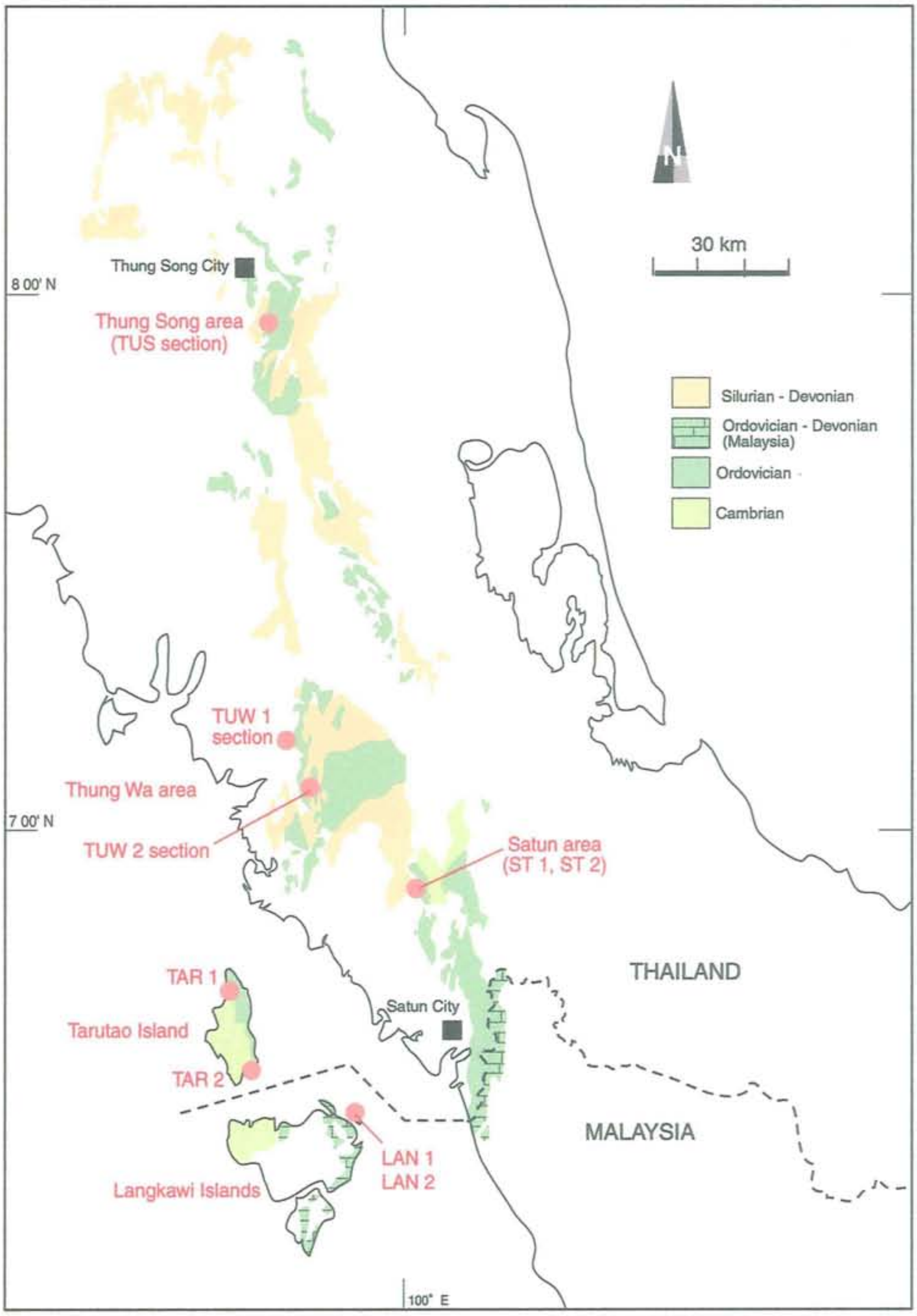

Figure 6. Distribution of the Ordovician to Devonian rocks in the southern peninsular Thailand and the northern peninsular Malaysia. Basic map is modified from Jones (1971) and Geological Map of Thailand, scale 1:2,500,000 (Department of Mineral Resources of Thailand, 2000).

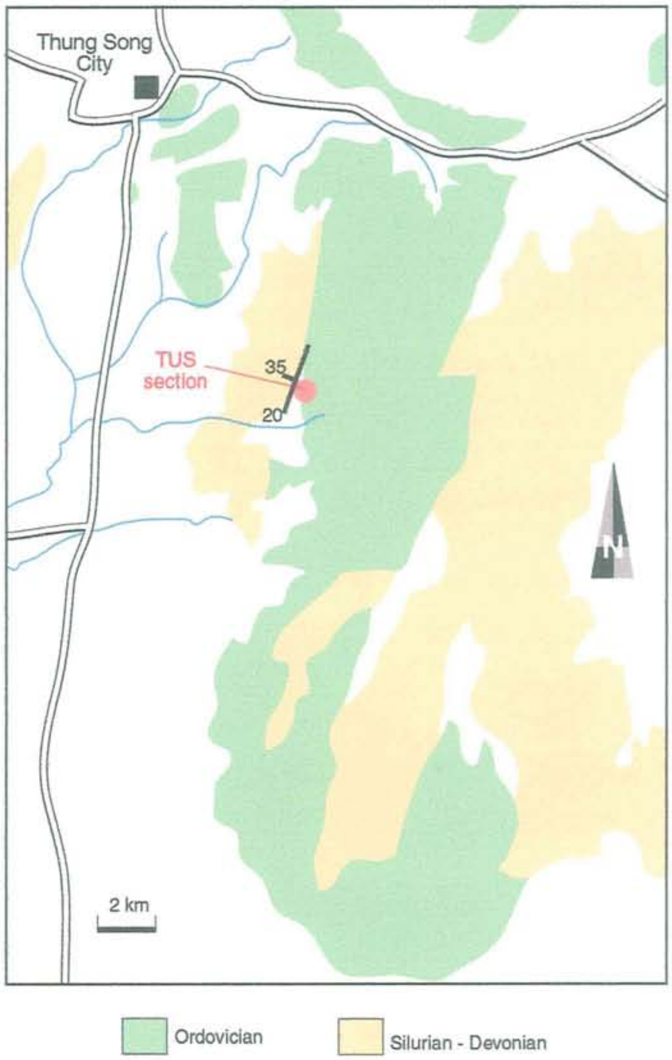

Figure 7. Simplified geologic map of the Thung Song area in southern peninsular Thailand. Basic map is Geological Map of Thailand, scale 1:2,500,000 (Department of Mineral Resources of Thailand, 2000).

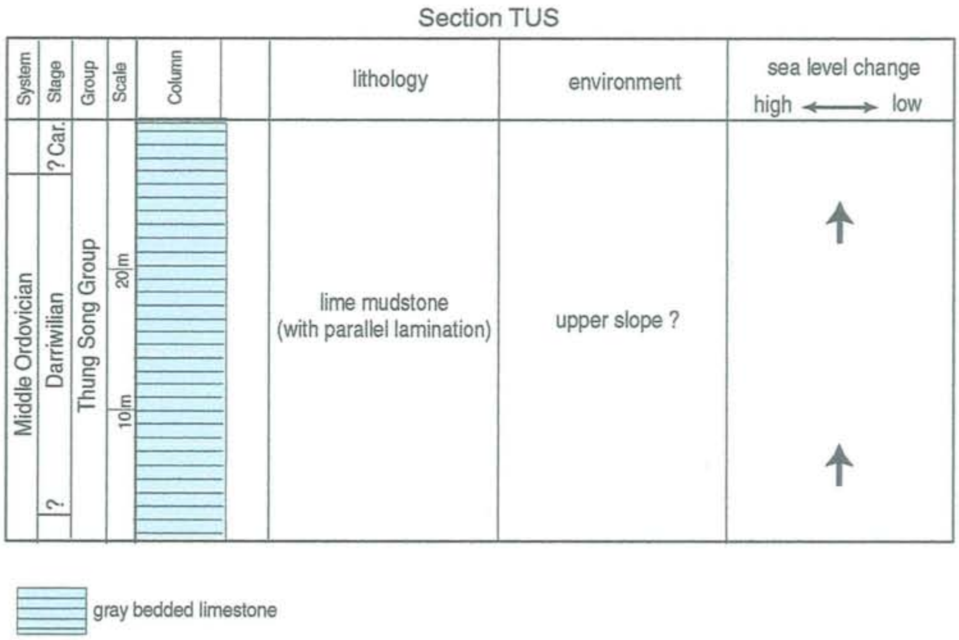

Figure 8. Lithologic column of the TUS section in the Thung Song area, and the reconstructed depositional environments and sea-level change.

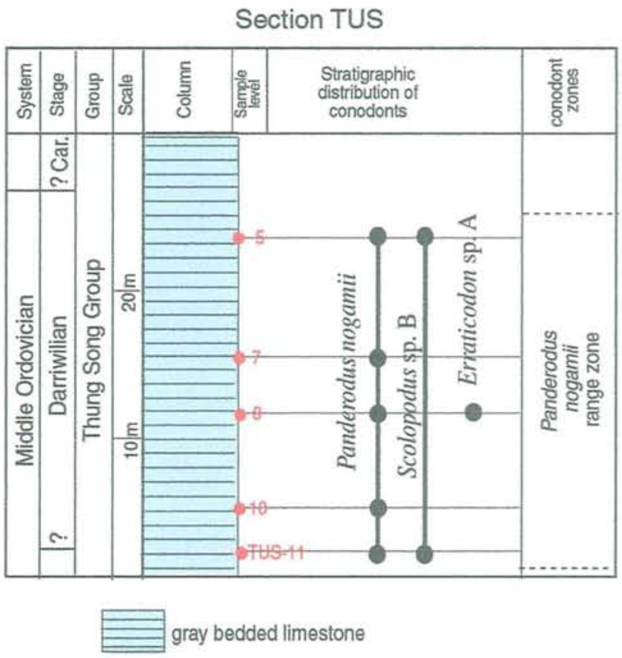

Figure 9. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the TUS section in the Thung Song area.

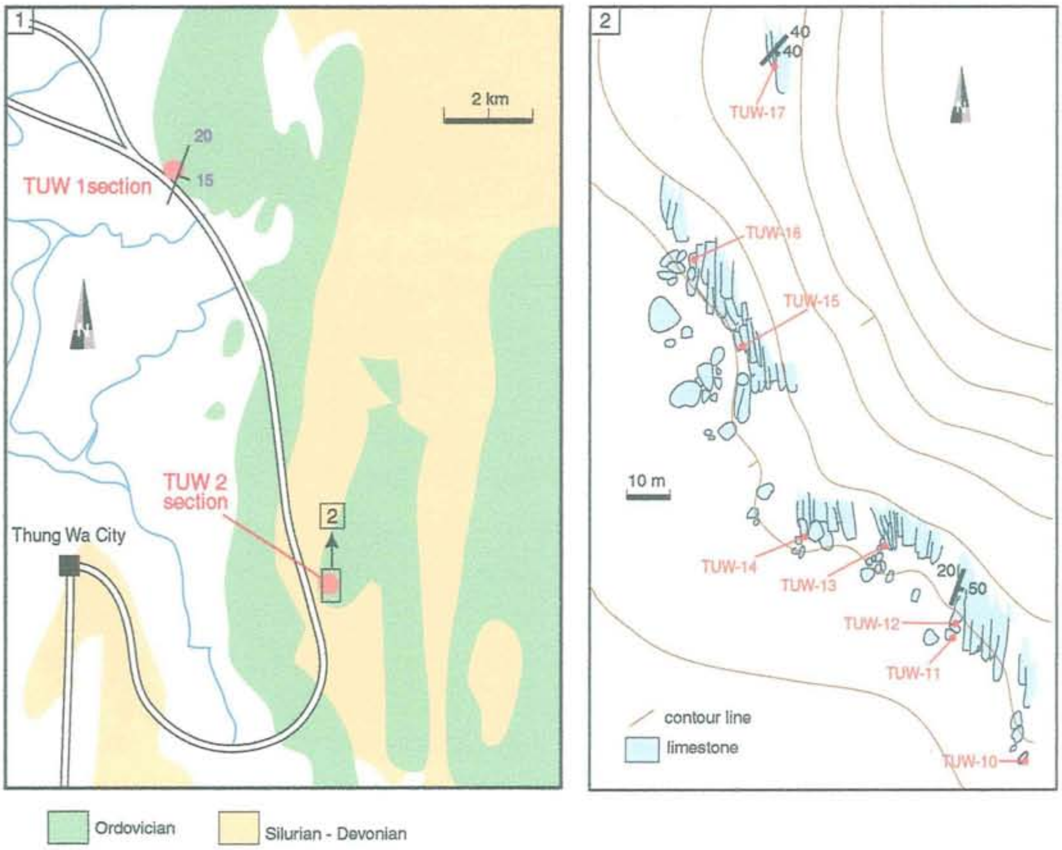

Figure 10. 1: Simplified geologic map of the Thung Wa area in southern peninsular Thailand. Basic map is Geological Map of Thailand, scale 1:2,500,000 (Department of Mineral Resources of Thailand, 2000).
2: Route map showing the sample localities and distribution of limestones in the TUW 2 section.

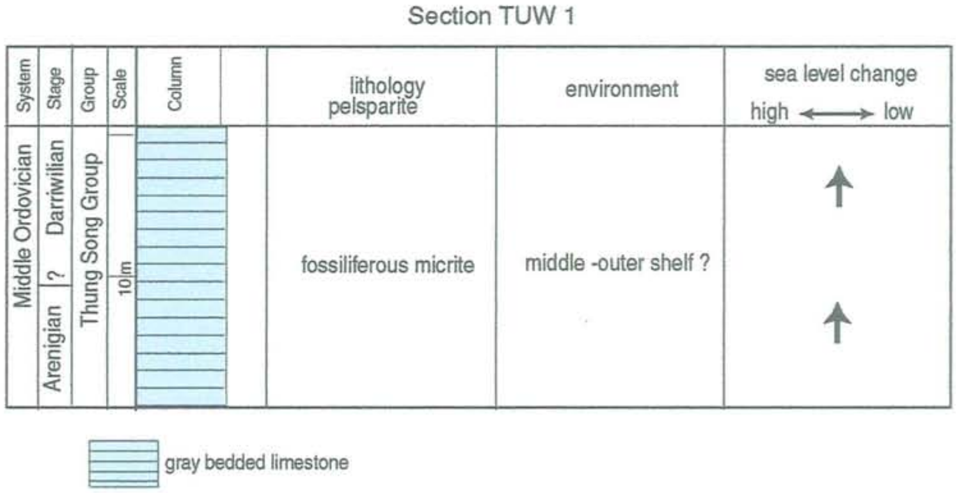

Figure 11. Lithologic column of the TUW 1 section in the Thung Wa area, and the reconstructed depositional environments and sea-level change.

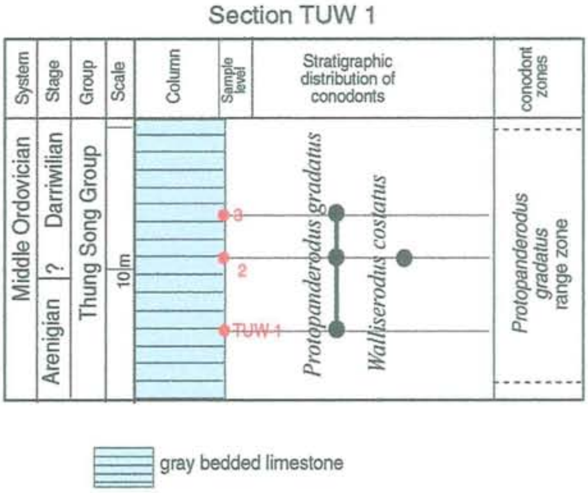

Figure 12. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the TUW 1 section in the Thung Wa area.

Section TUW 2

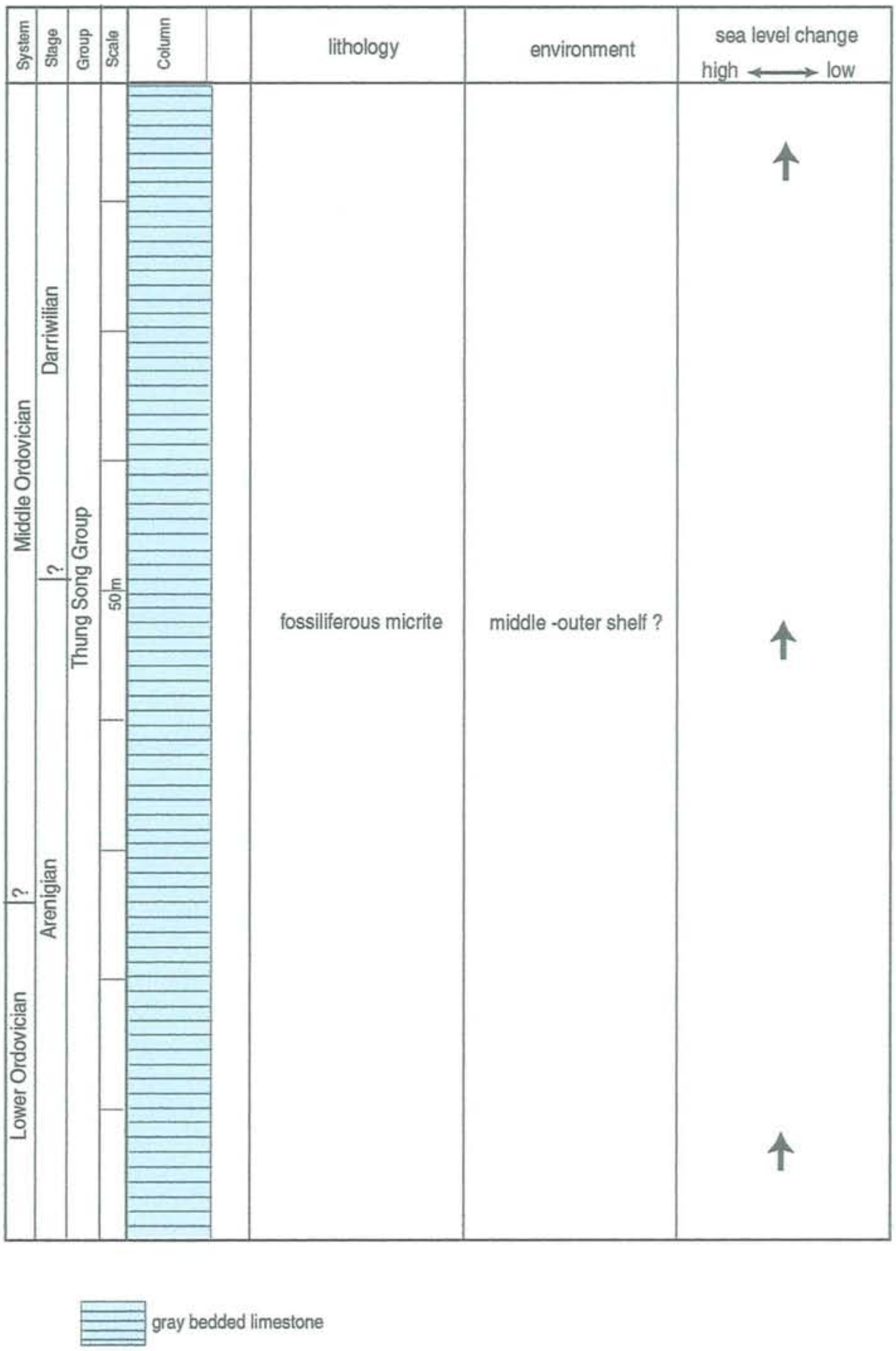

Figure 13. Lithologic column of the TUW 2 section in the Thung Wa area, and the reconstructed depositional environments and sea-level change.

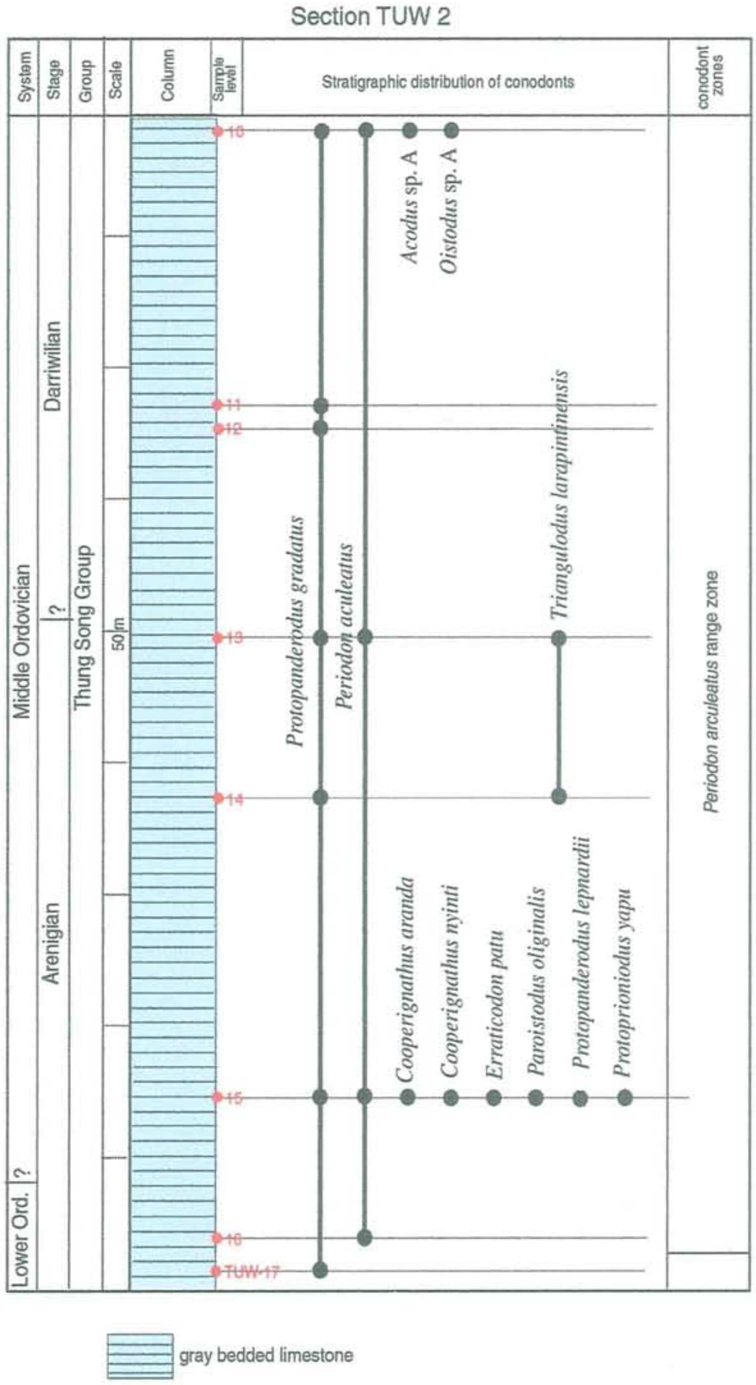

Figure 14. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the TUW 2 section in the Thung Wa area.

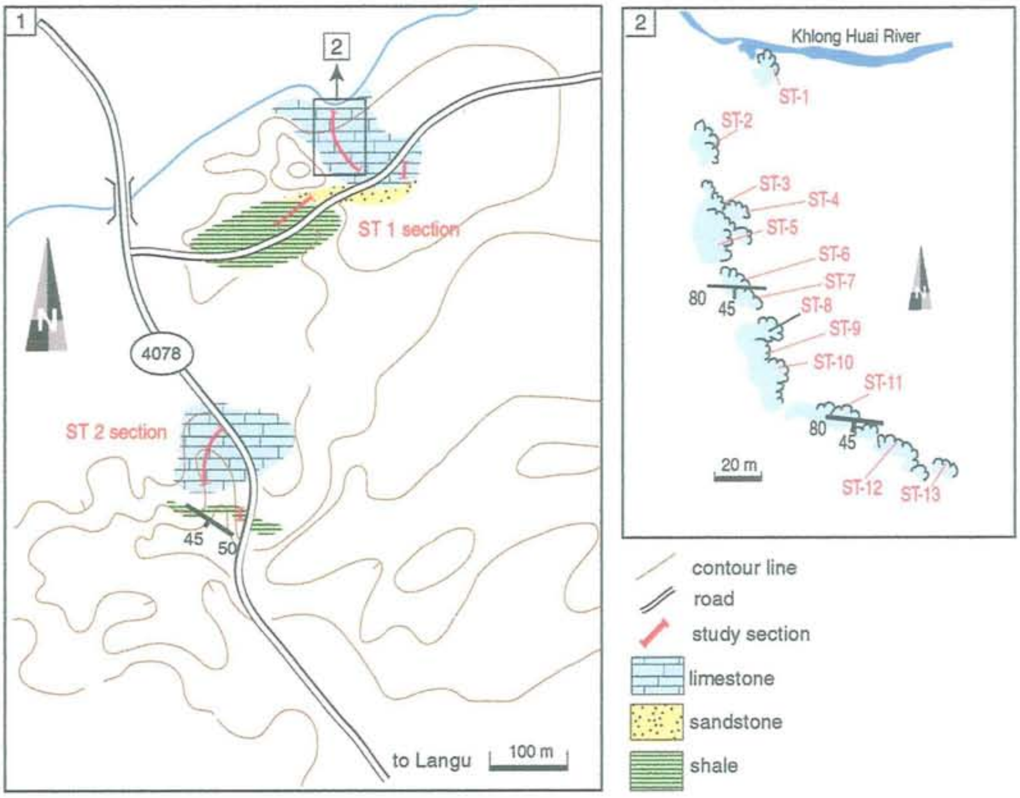

Figure 15. Route map showing the distribution of sedimentary rocks and sample localities in the Satun area.

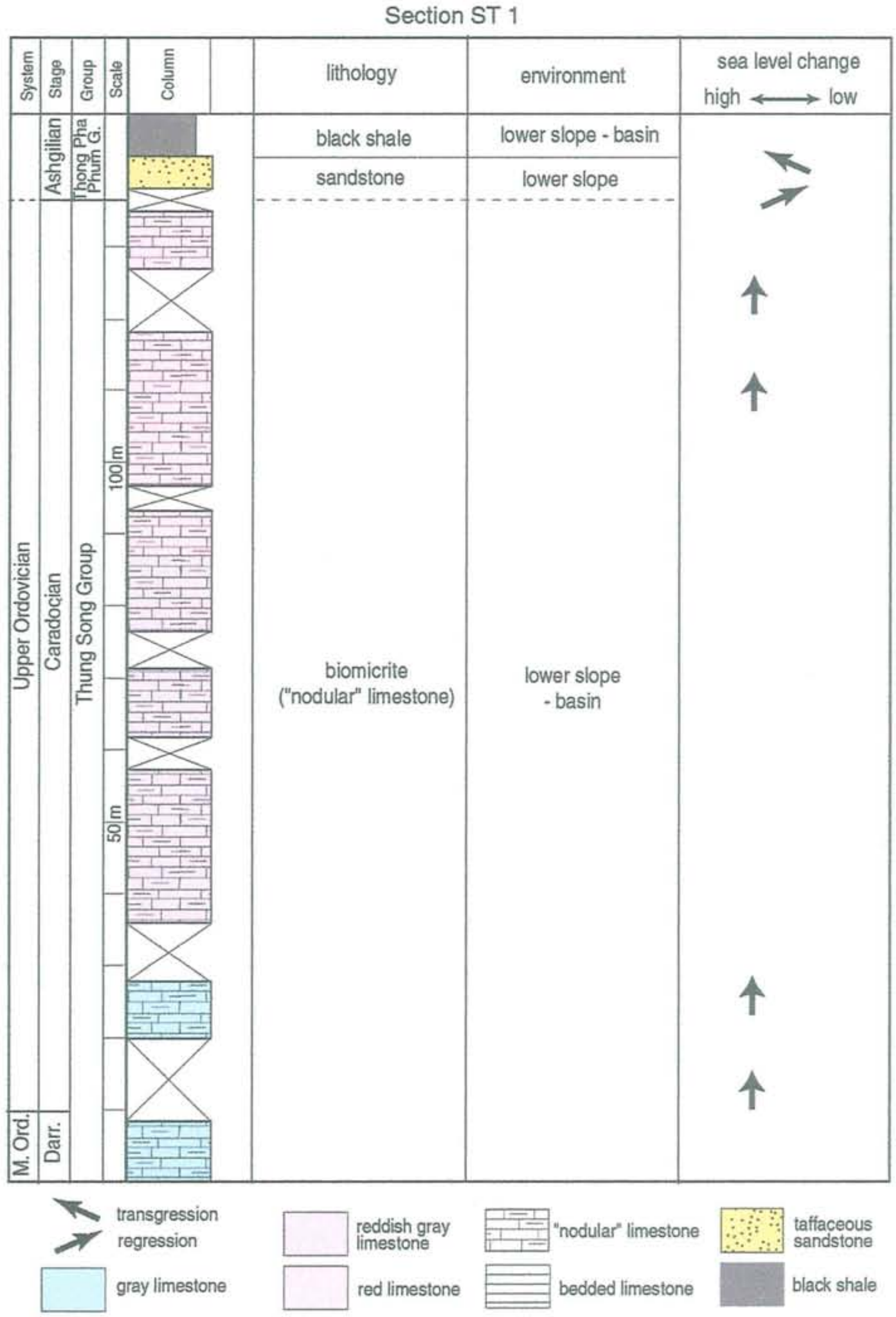

Figure 16. Lithologic column of the ST 1 section in the Satun area, and the reconstructed depositional environments and sea-level change.

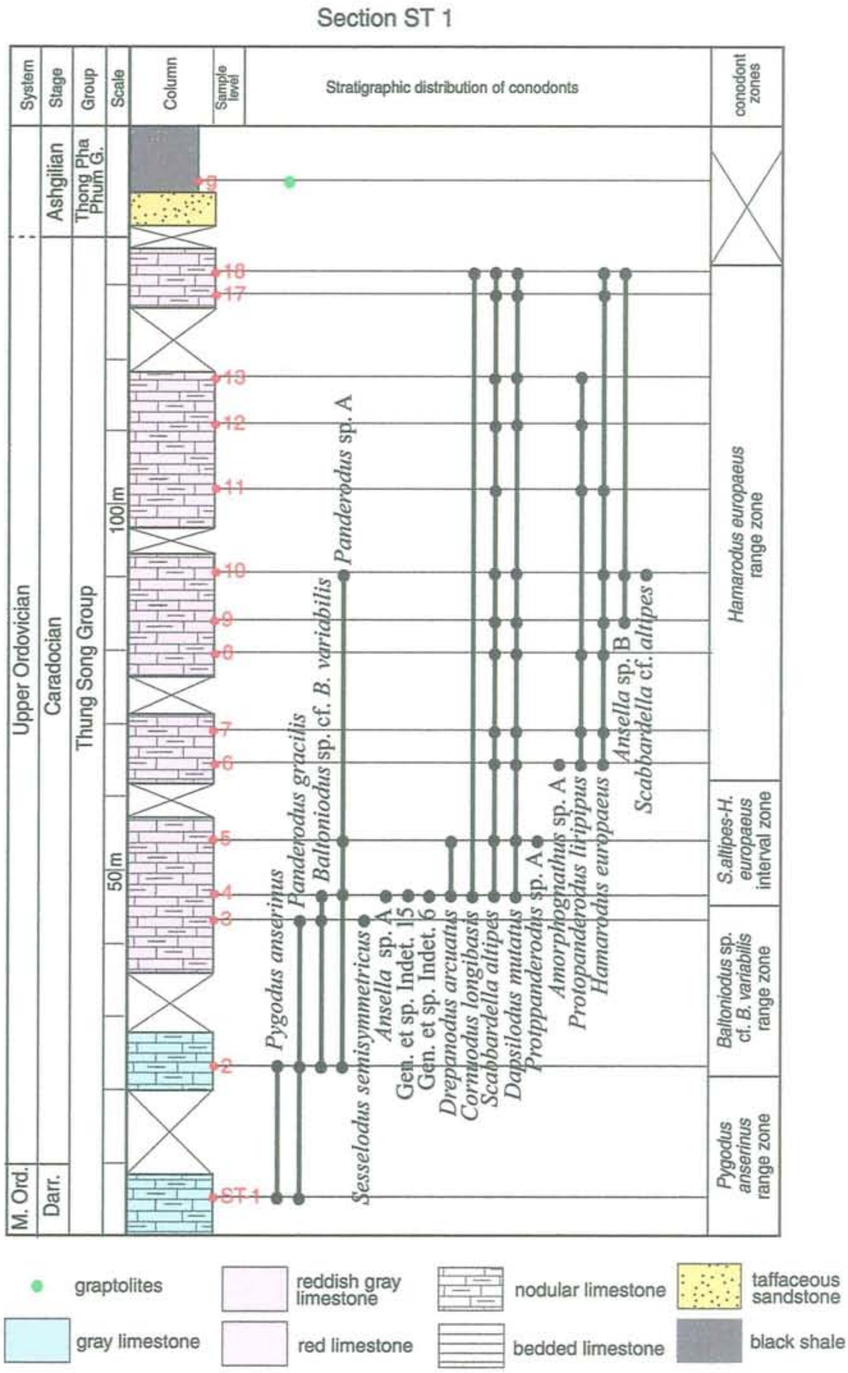

Figure 17. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the ST1 section in the Satun area.

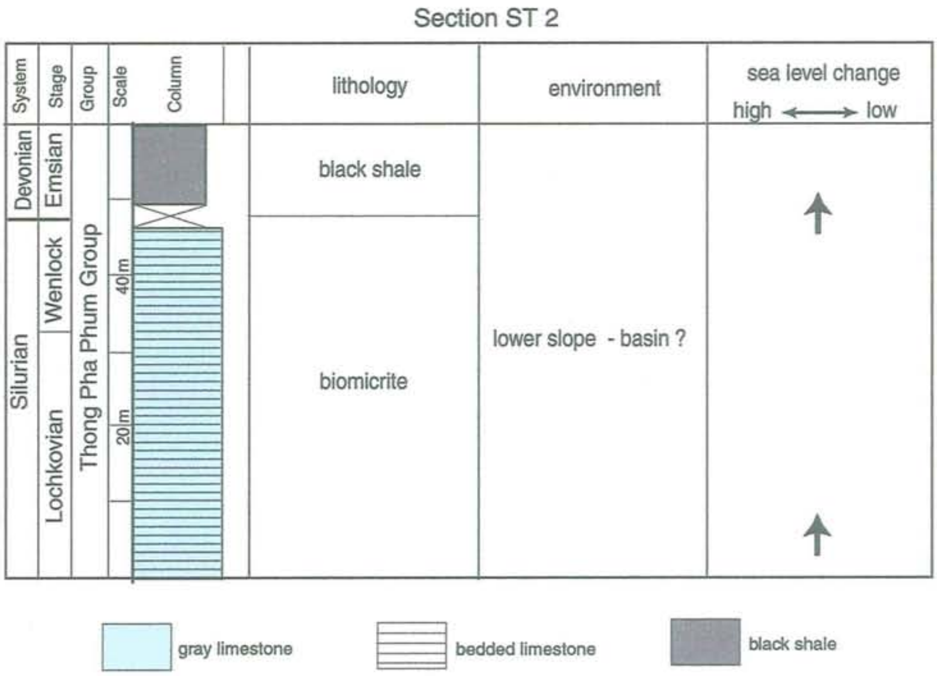

Figure 18. Lithologic column of the ST 2 section in the Satun area, and the reconstructed depositional environments and sea-level change.

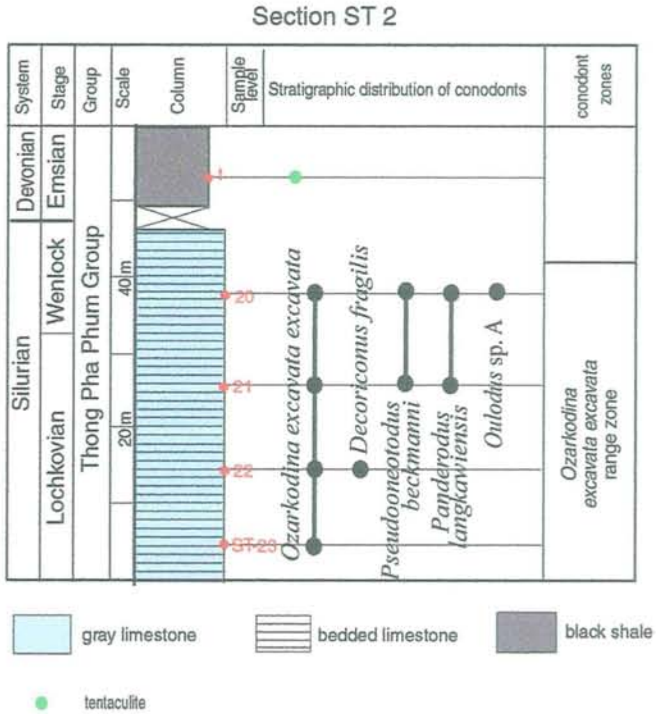

Figure 19. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the ST 2 section in the Satun area.

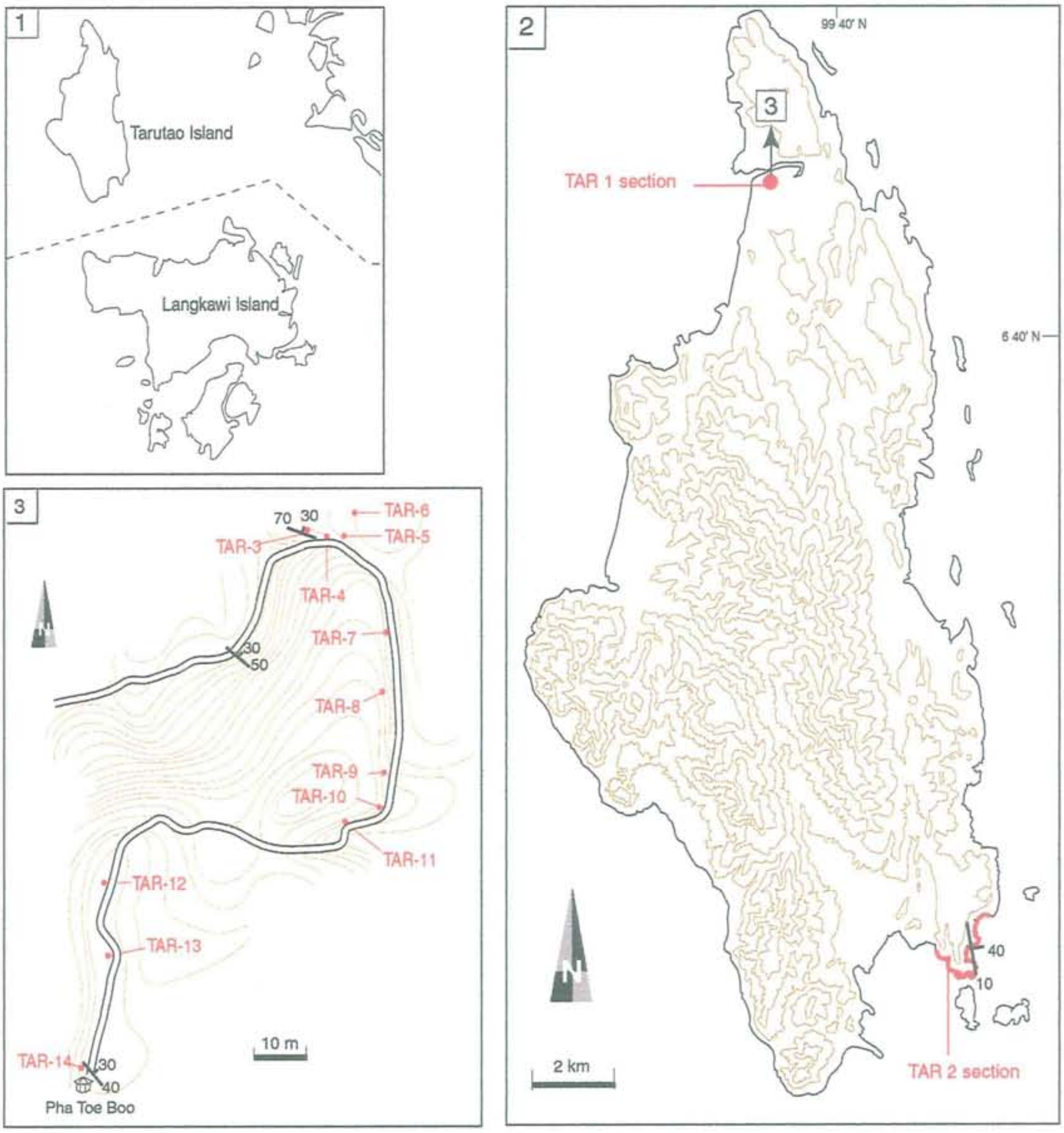

Figure 20. 1: Index map showing the location of Tarutao Island.
2: Index map showing the TAR 1 and TAR 2 sections in Tarutao Island.
3: Route map showing the sample localities of the TAR 1 section.

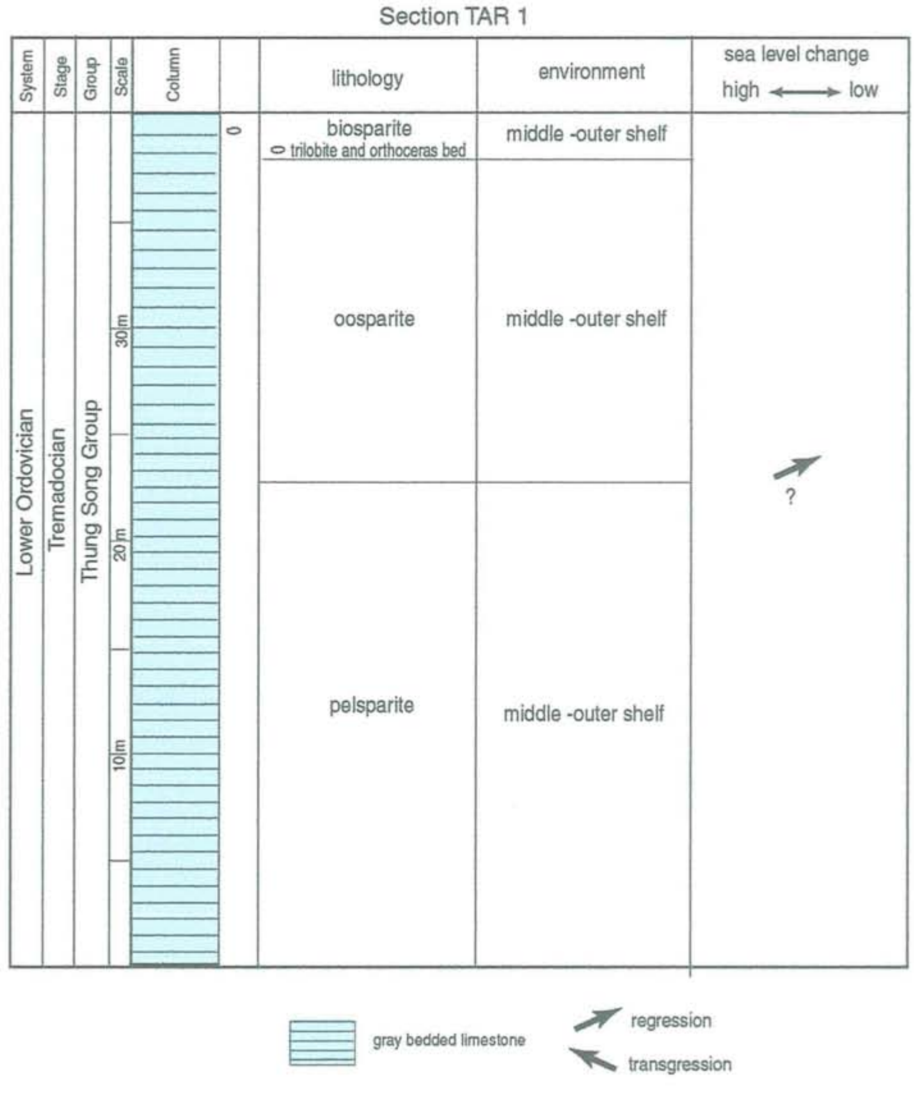

Figure 21. Lithologic column of the TAR 1 section in Tarutao Island and the reconstructed depositional environments and sea-level change.

Section TAR 1

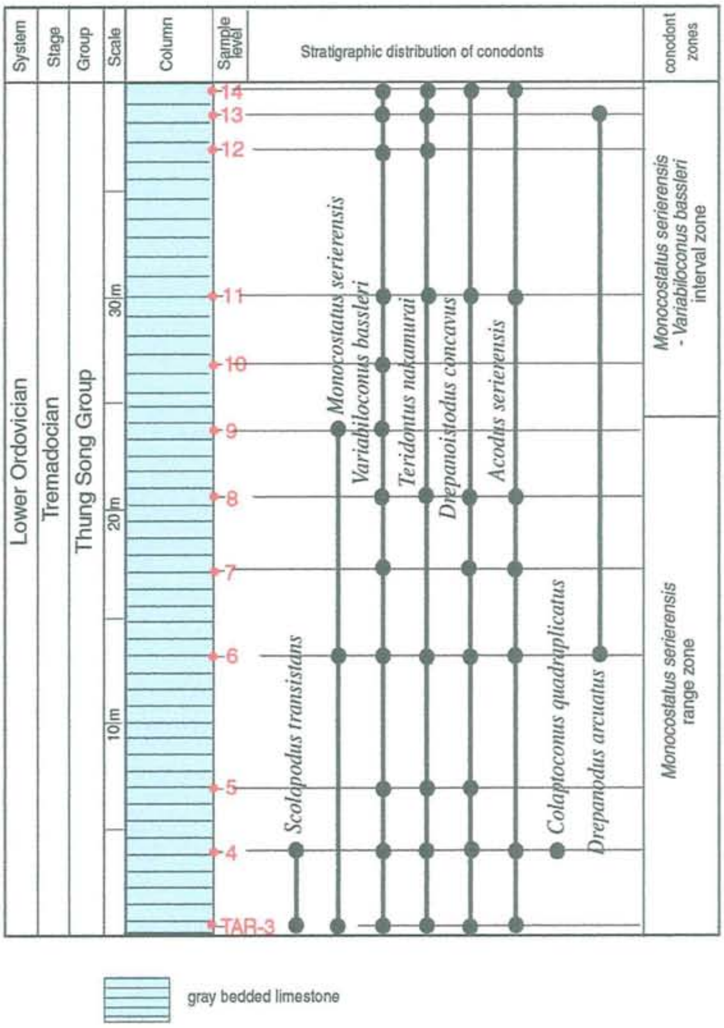

Figure 22. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the TAR 1 section in Tarutao Island.

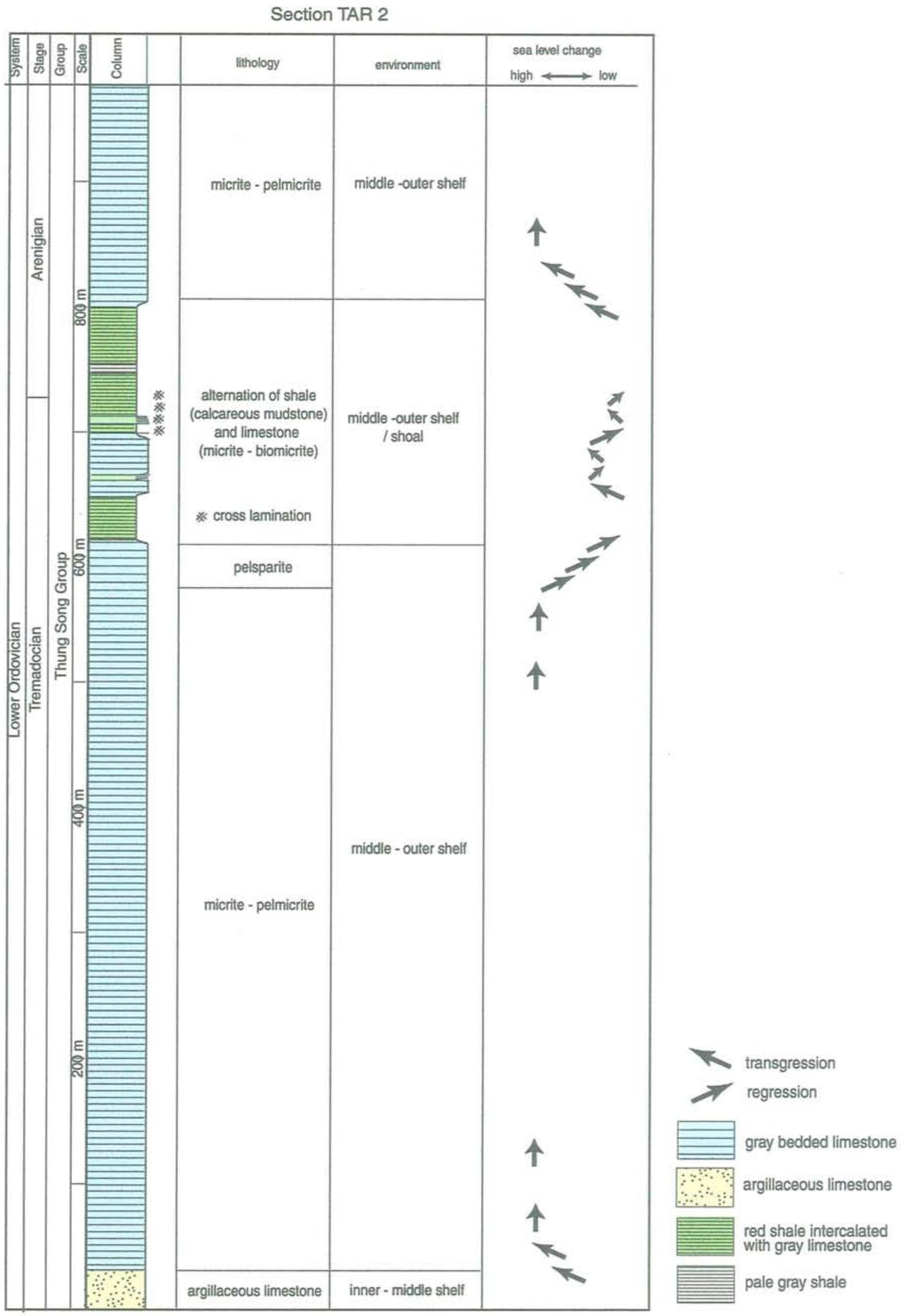

Figure 23. Lithologic column of the TAR 2 section in Tarutao Island and the reconstructed depositional environments and sea-level change.

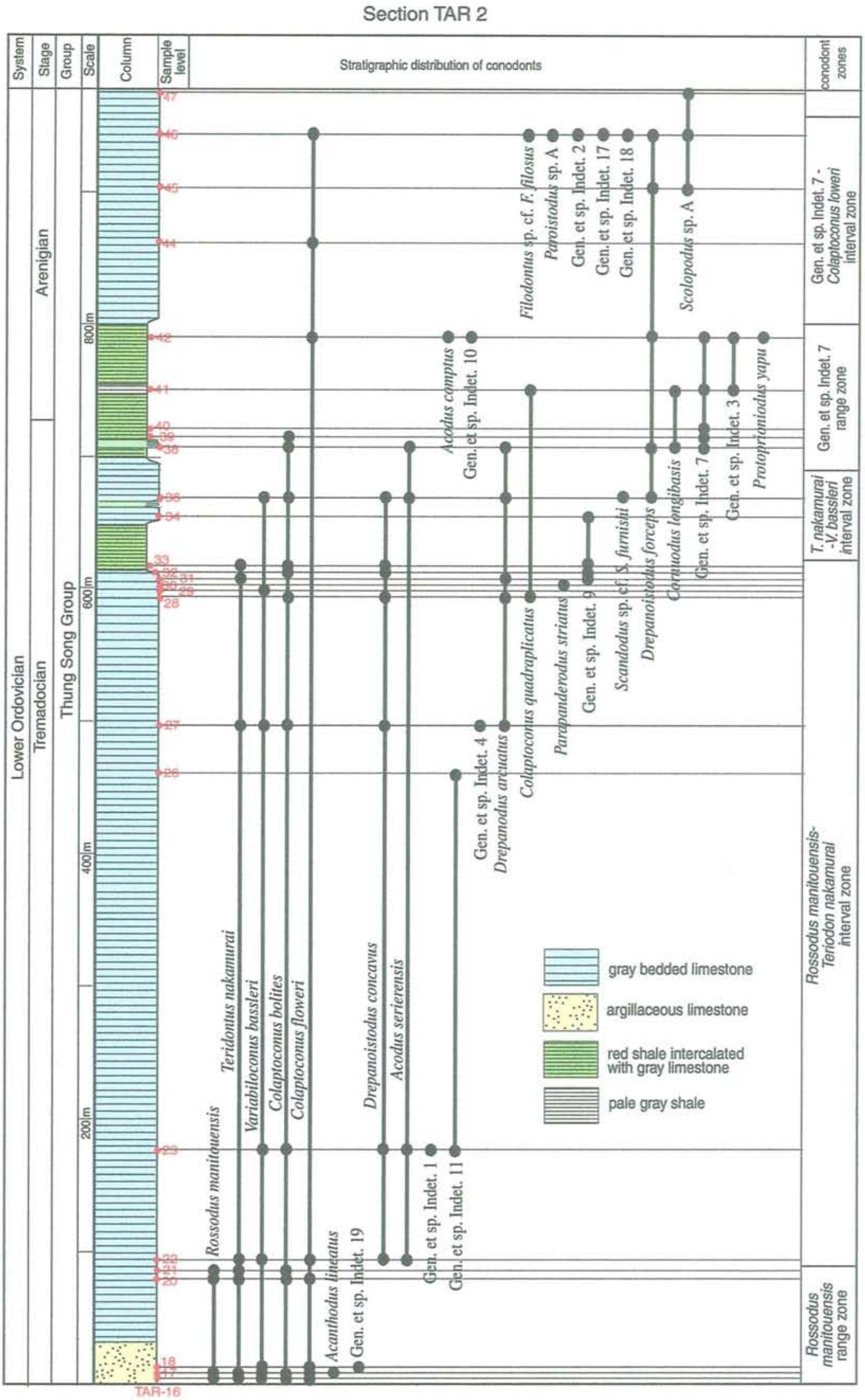

Figure 24. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the TAR 2 section in Tarutao Island.

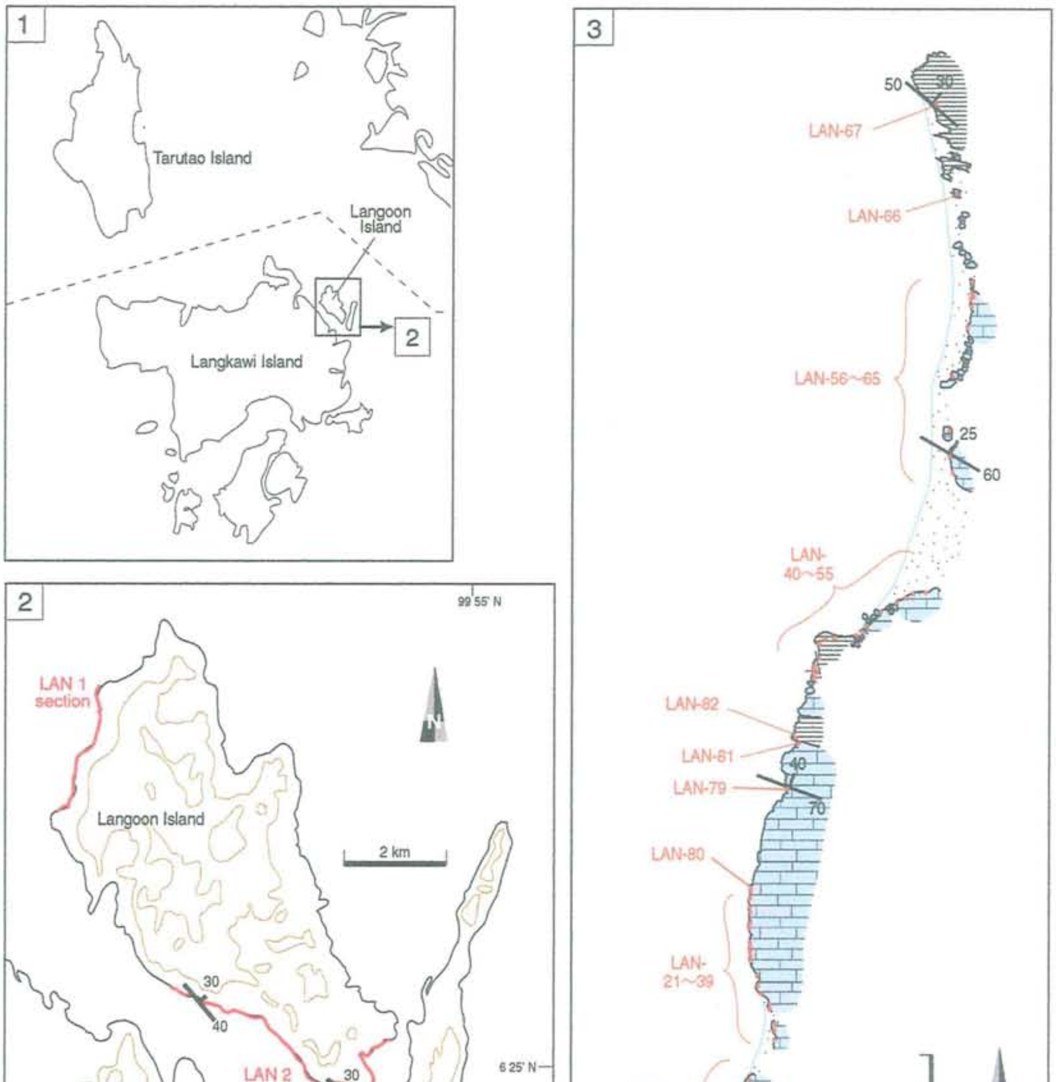

Figure 25. 1: Index map showing the location of the Langkawi Islands.
2: Index map showing the LAN 1 and LAN 2 sections in the Langkawi Islands.
3: Route map showing the sample localities of the LAN 1 section

Section LAN 1

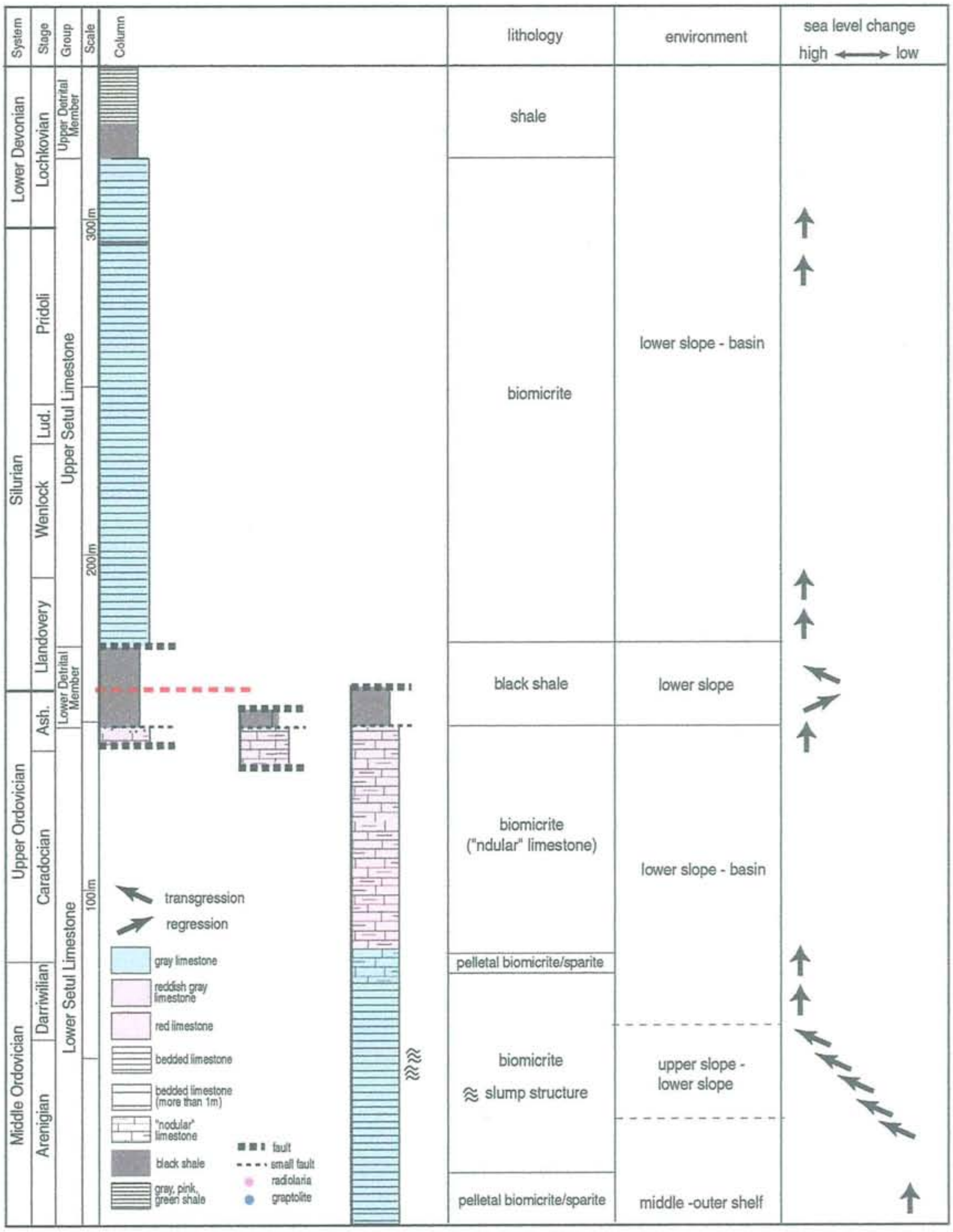

Figure 26. Lithologic column of the LAN 1 section in the Langkawi Islands and the reconstructed depositional environments and sea-level change.

Section LAN 1

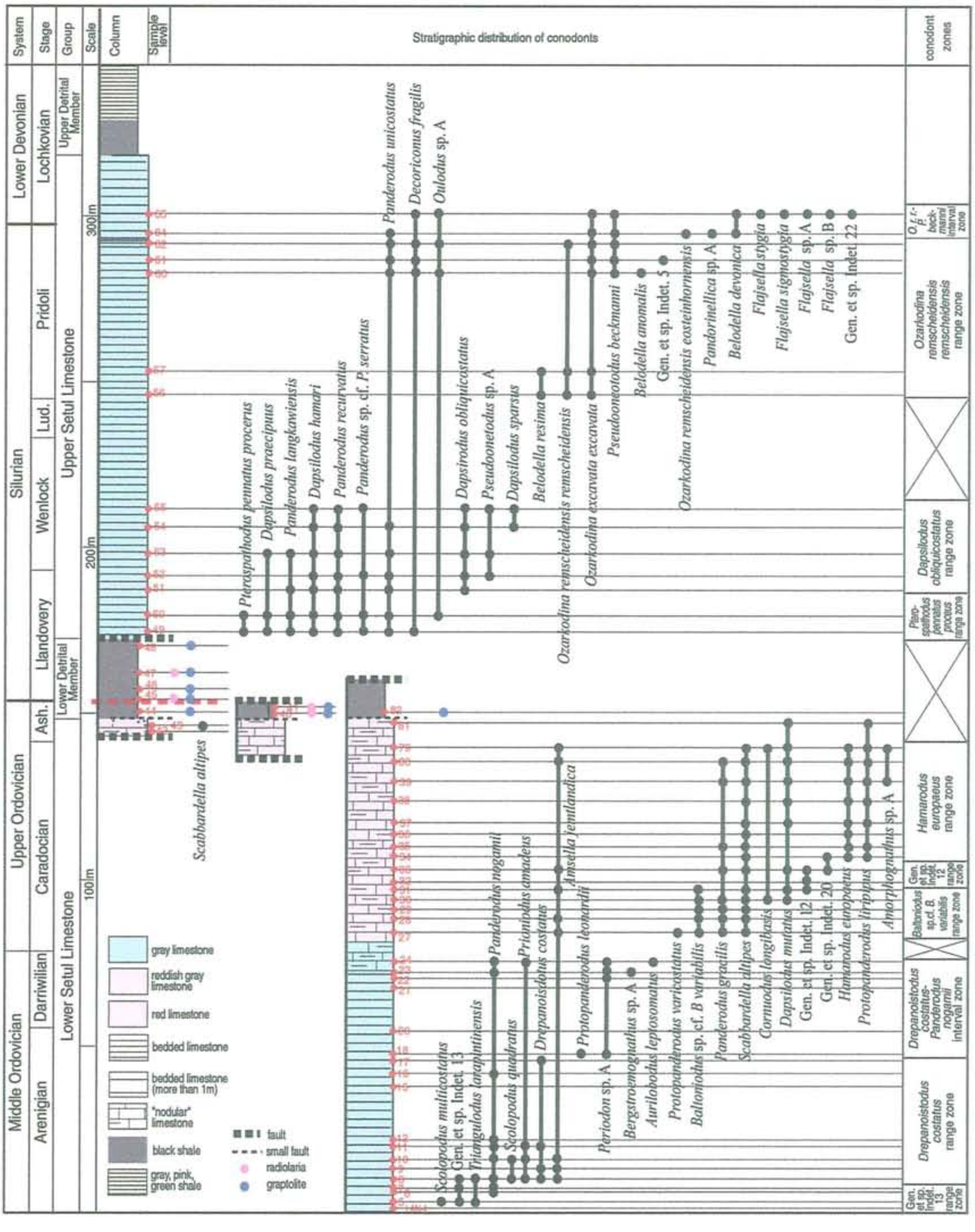

Figure 27. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the LAN 1 section in the Langkawi Islands.

Section LAN 2

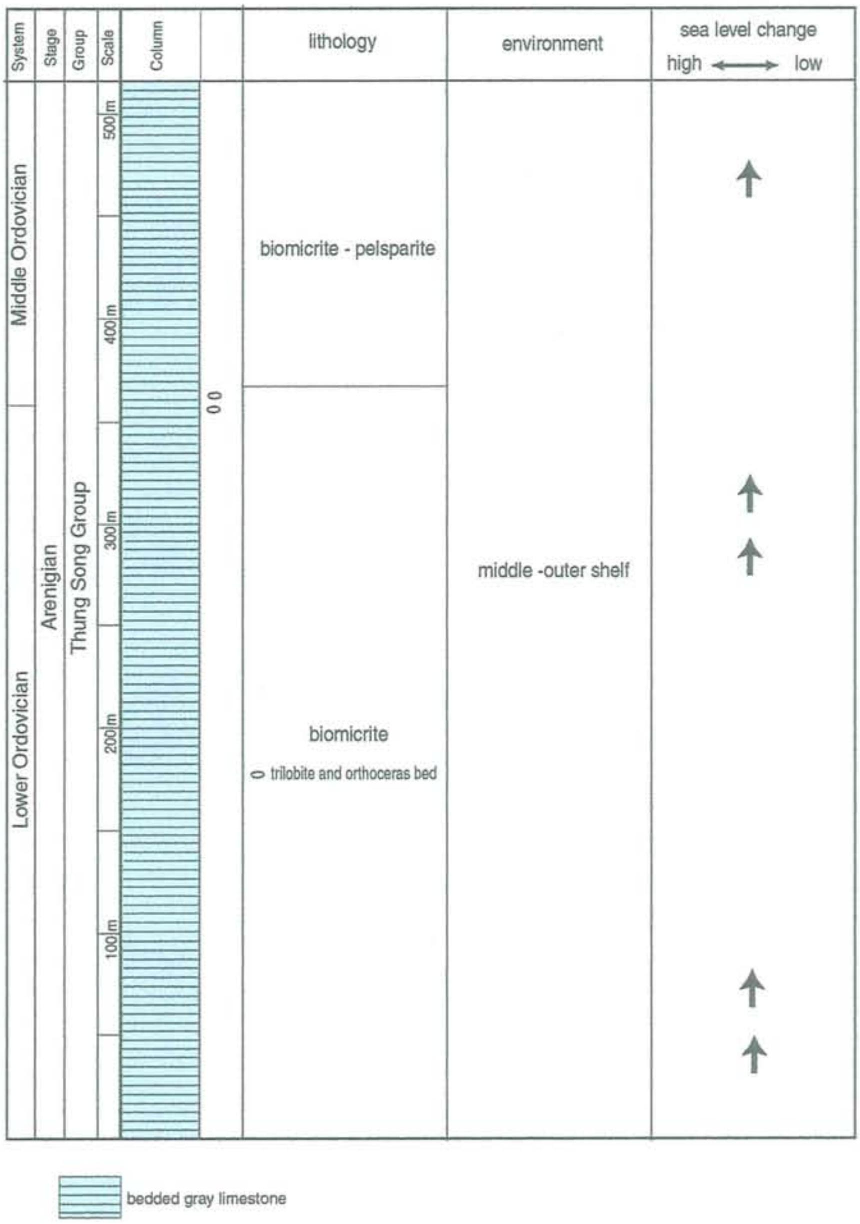

Figure 28. Lithologic column of the LAN 2 section in the Langkawi Islands and the reconstructed depositional environments and sea-level change.

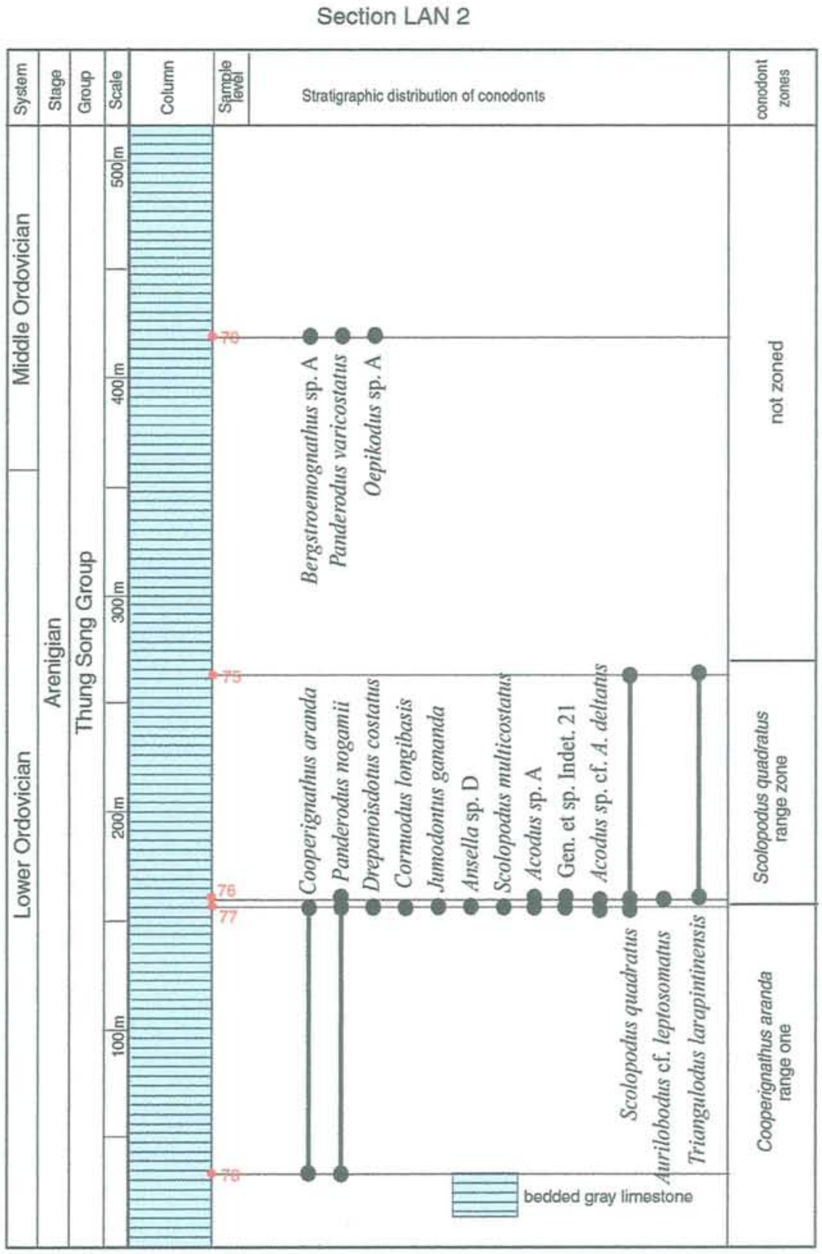

Figure 29. Lithologic column and stratigraphic distributions of conodont species and conodont zones of the LAN 2 section in the Langkawi Islands.

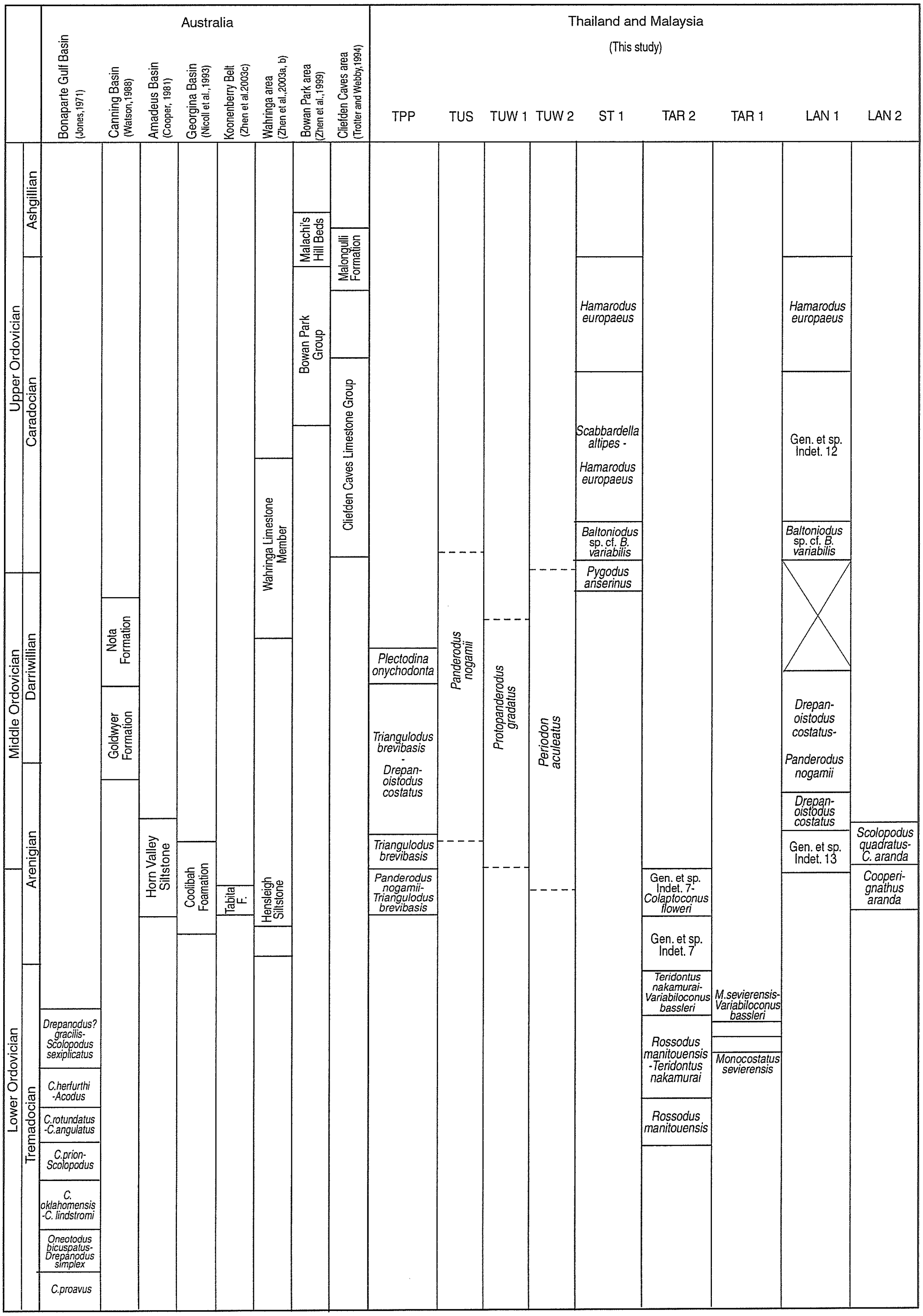

Figure 30. Correlation of the Ordovician conodont zones of the study sections with representative Ordovician sequences in Australia.

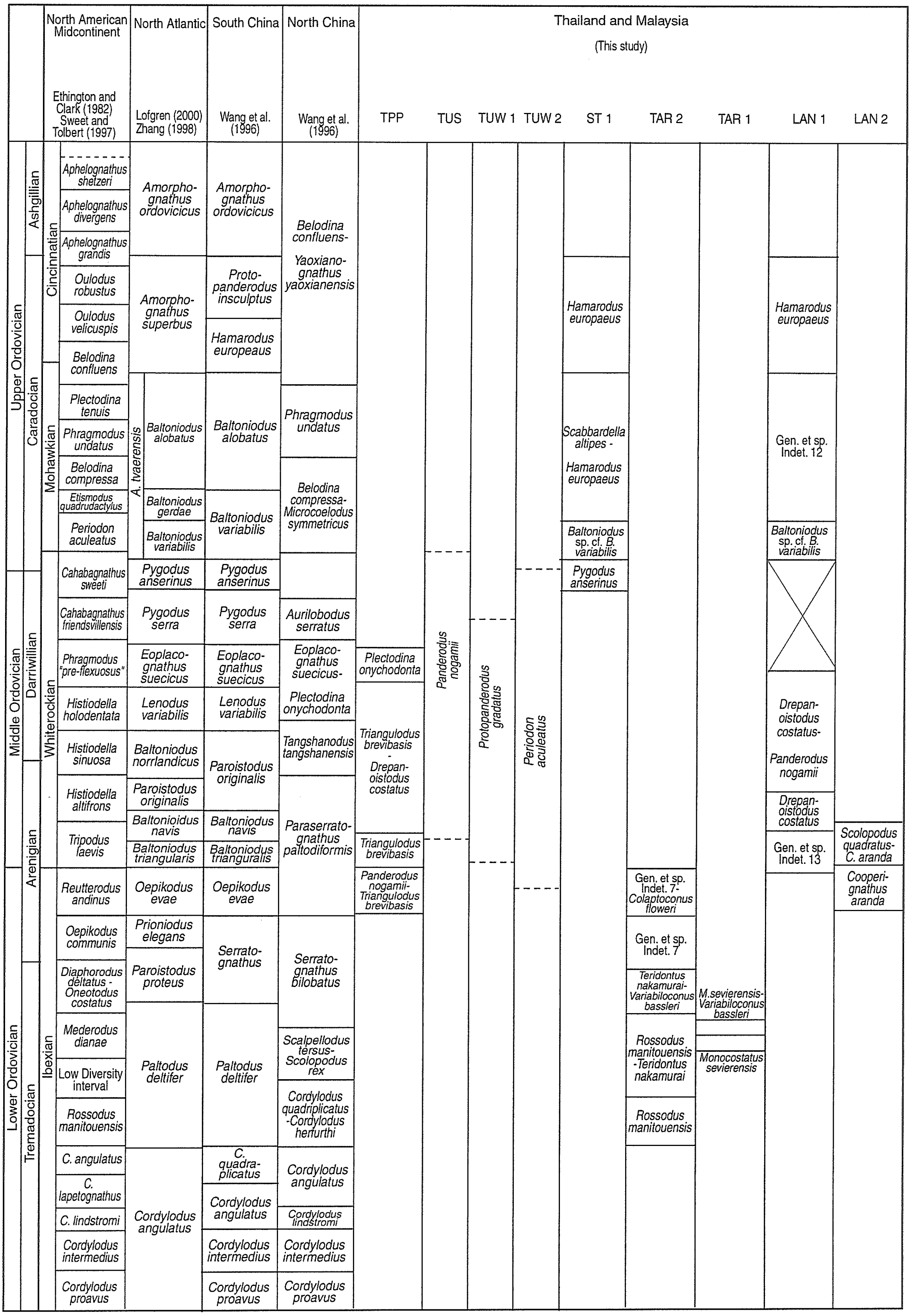

Figure 31. Correlation of the Ordovician conodont zones of the study sections with those of North America, North Atlantic, North China, and South China.

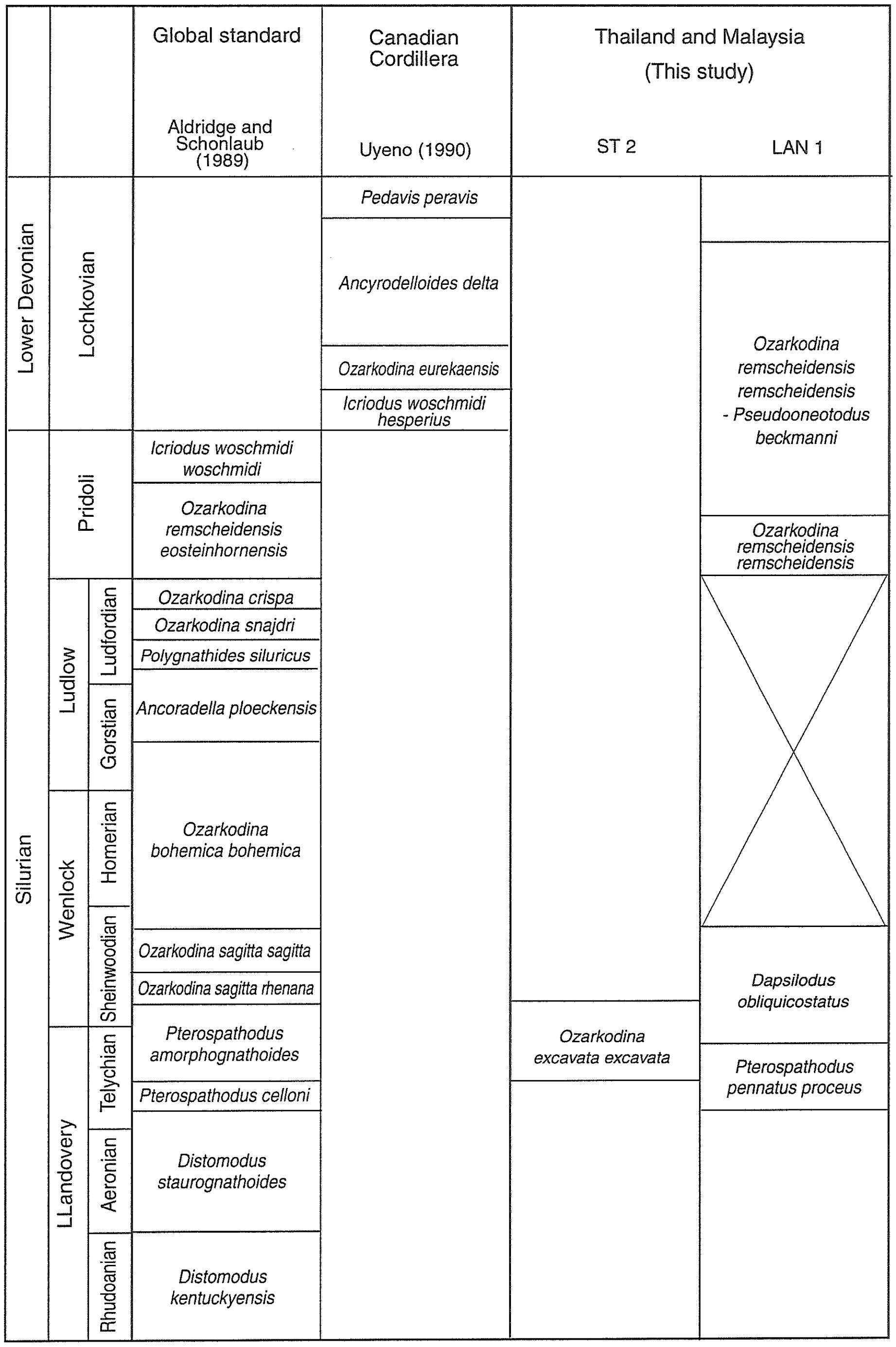

Figure 32. Correlation of the Sillurian and Devonian conodont zones of the study sections with those of Global Standard and the Canadian Cordillela.

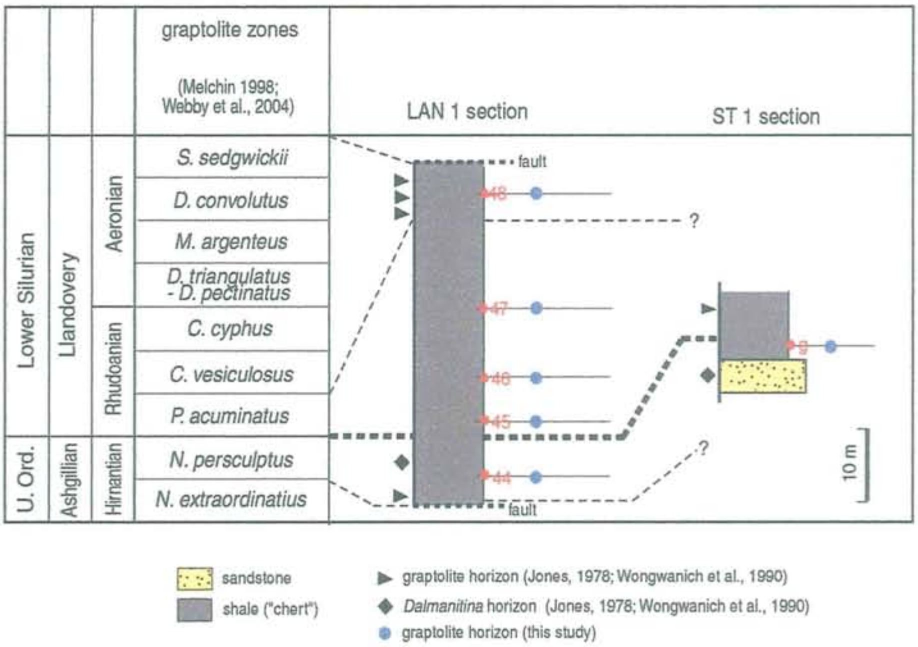

Figure 33. Column of the siciliclastic sequences of the ST 1 and LAN 1 sections and graptolite biostratigraphy.

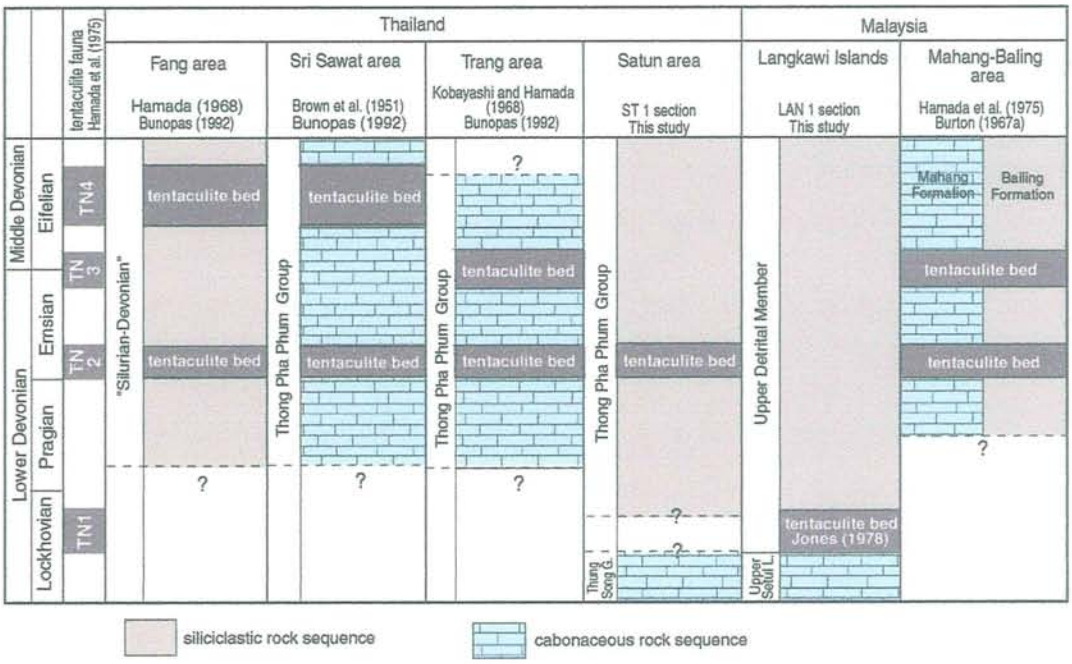

Figure 34. Correlation of the tentaculite beds in Thailand and Malayasia.

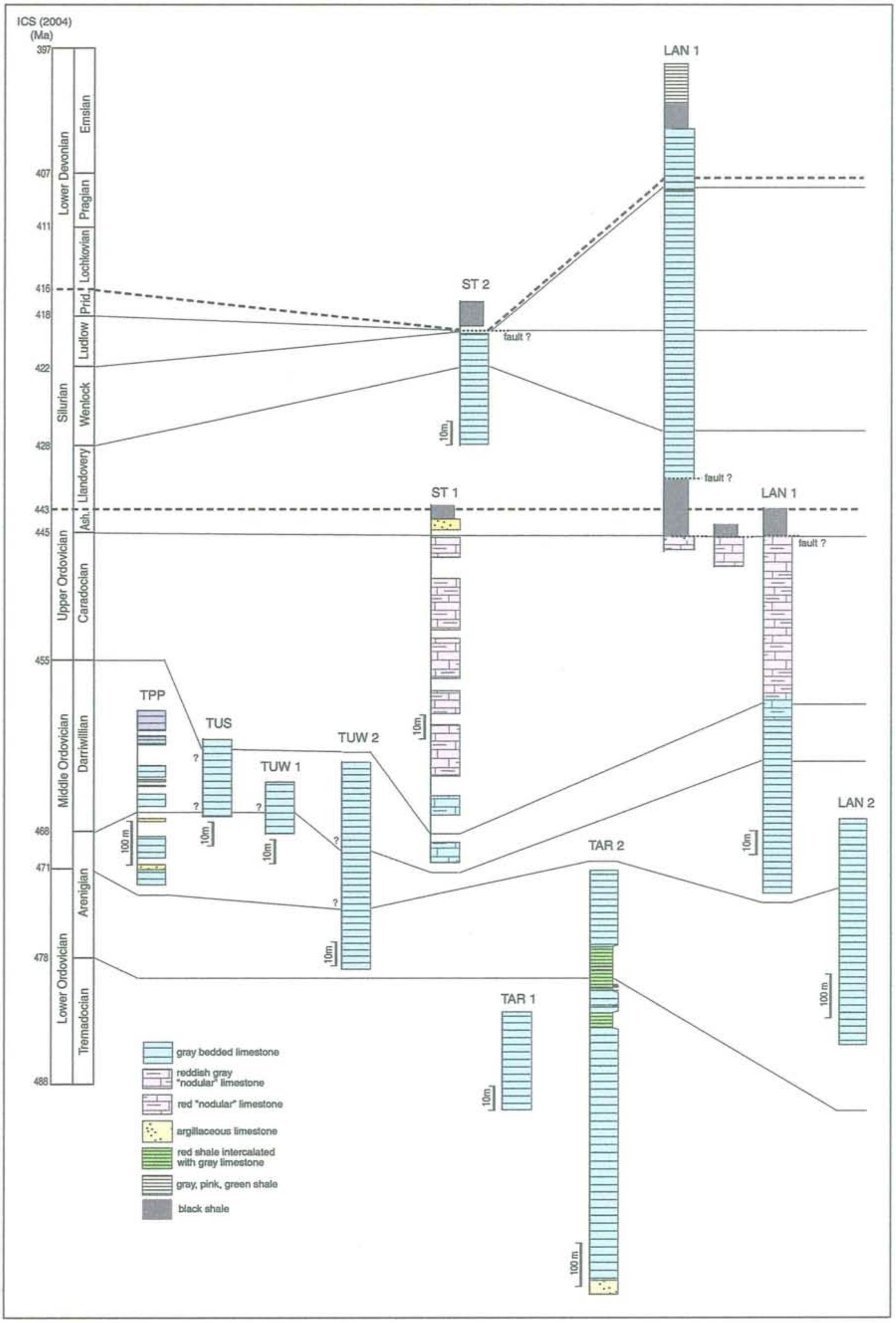

Figure 35. All columns of the study sections and the Ordovician - Silurian and Silurian - Devonian boundaries.

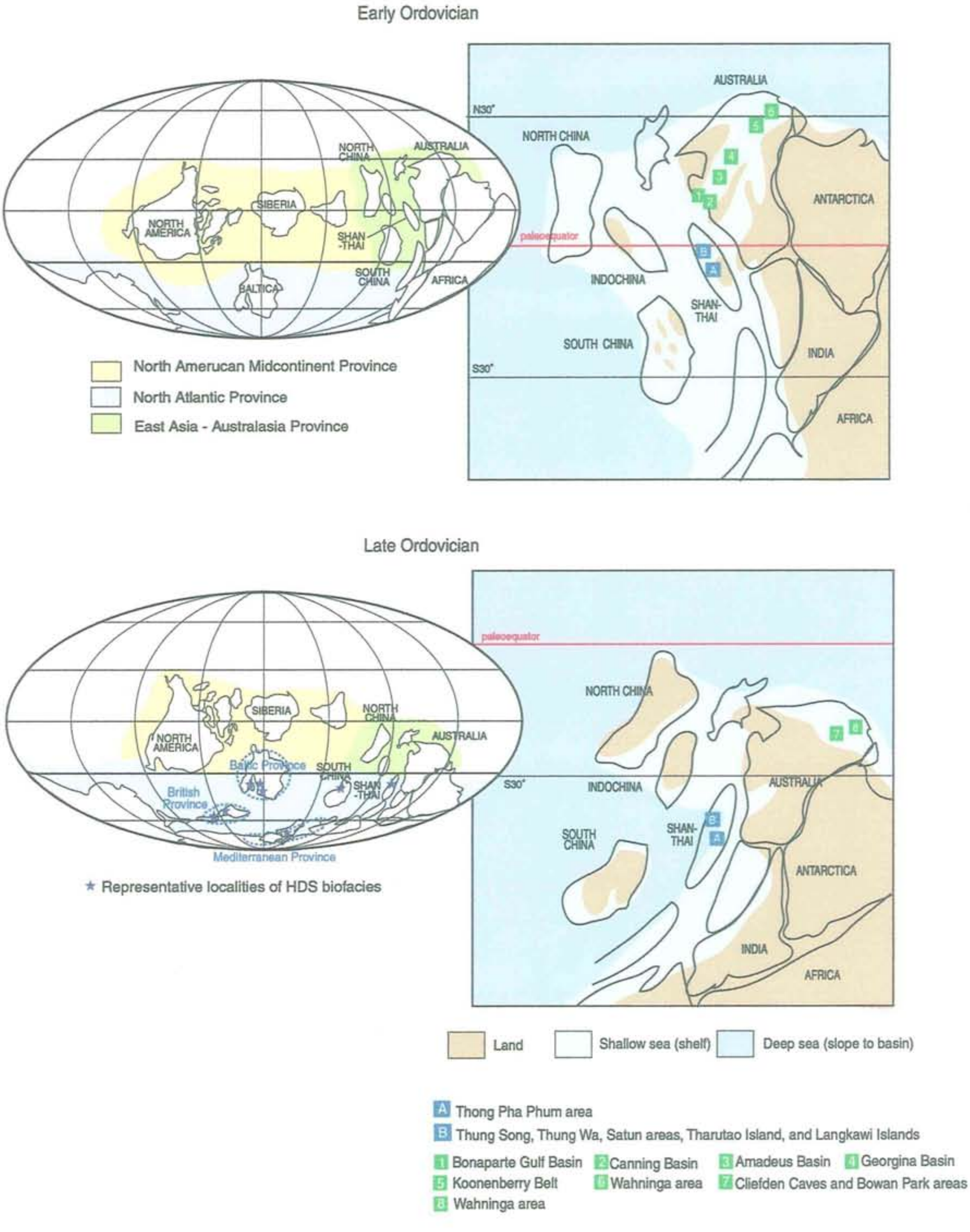

Figure 36. Early and Late Ordovician palegeographic maps.
Basic map is modified from Scotese and McKerow (1991) and Metcalfe (1999).

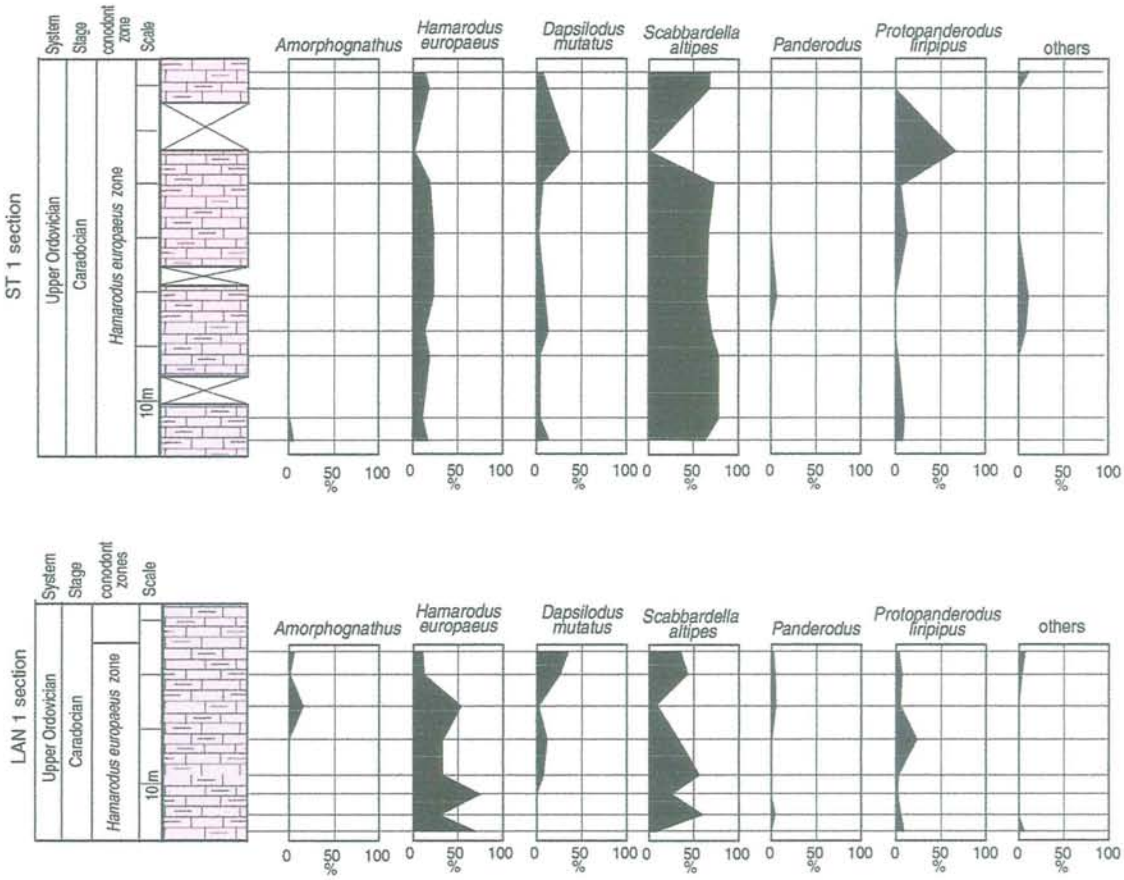

Figure 37. Relative frequencies of dominant conodont taxa in the ST 1 and LAN 1 sections. (element number of each taxon / total number of element, contained in each sample)

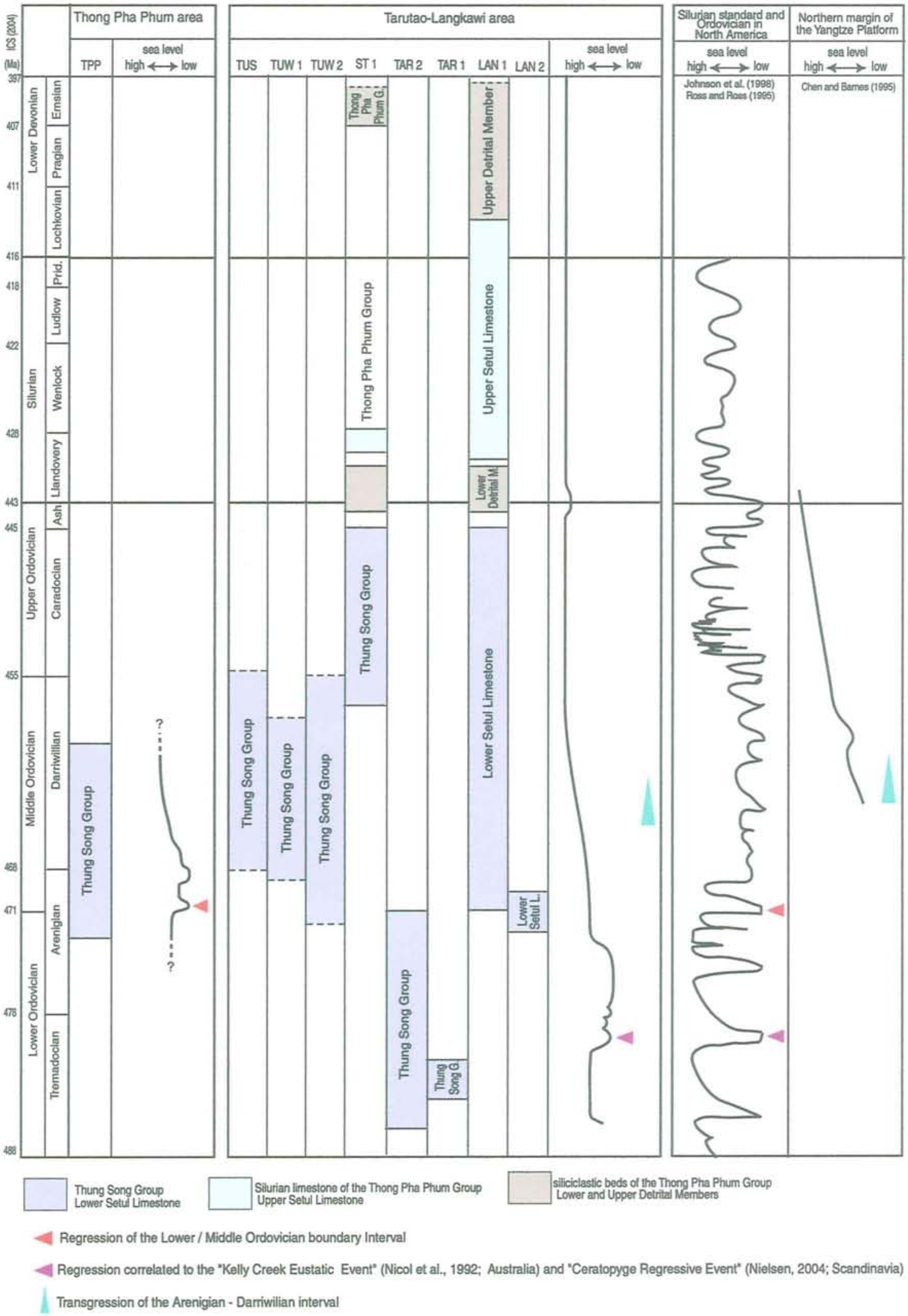

Figure 38. Sea-level curves of the Thong Pha Phum and Tarutao - Langkawi areas and their correlation with those of North Amrica and South China.

Table 1. List of conodont species from the Thong Pha Phum area.
About 1.5 kg limestones were processed for each sample.

Thong Pha Phum area Section TPP											
sample number species	TPP 22	21	24	28	27	11	13	15	18	17	total
Ansella sp. C									2		2
Ansella sp. D					1						1
Aurilobodus cf. *leptosomatus*							1				1
Aurilobodus leptosomatus								1			1
Bergstroemognathus sp .B								2			2
Drepanodus arcuatus										1	1
Drepanoistodus costatus					1	1			1		3
Erraticodon sp. B					2						2
Gen. et sp. Indet. 14									1		1
Gen. et sp. Indet. 16									2	2	4
Gen. et sp. Indet. 8									2		2
Histiodella holodentata								1			1
Juanognathus variabilis		1									1
Panderodus nogamii	2	1	2	6	2	8			4	3	28
Periodon sp. B										1	1
Plectodina onychodonta									1		1
Scolopodus sp. C						2					2
Triangulodus brevibasis			1	2	1						4
Triangulodus larapinensis									1		1
total	1	2	3	8	7	11	1	4	14	7	58

Table 2. List of conodont species from the Thung Song area.
About 1.5 kg limestones were processed for each sample.

Thung Song area						
Section TUS						
sample number / species	TUS 5	7	8	10	11	total
Erraticodon sp. A			1			1
Panderodus nogamii	2	1	1	2	2	8
Scolopodus sp. B	1				1	2
total	3	1	2	2	3	11

Table 3. List of conodont species from the TUW 1 section in the Thung Wa area

About 1.5 kg limestones were processed for each sample.

Thung Wa area				
Section TUW 1				
sample number / species	TUW 1	2	3	total
Protopanderodus gradatus	8	1	1	10
Walliserodus costatus		2		2
total	8	3	1	12

Table 4. List of conodont species from theTUW 2 section in the Thung Song area.
About 1.5 kg limestones were processed for each sample.

	Thung Wa area								
	Section TUW 2								
sample number / species	TUW 10	11	12	13	14	15	16	17	total
Acodus sp. C	4								4
Cooperignathus aranda						8			8
Cooperignathus nyinti						26			26
Erraticodon patu						1			1
Oistodus sp. A	2								2
Paroistodus originalis						32			32
Periodon aculeatus	1			1		2	2		6
Protopanderodus gradatus	12	5	5	2	4	29	11	2	70
Protopanderodus leonardii						4			4
Protoprioniodus yapu						19			19
Triangulodus larapintinensis				1	2				3
total	19	5	5	4	6	121	13	2	139

Table 5. List of conodont species from the ST 1 section in the Satun area.
About 1.5 kg limestones were processed for each sample.

Satun area Section ST 1																
sample number species	ST 1	2	3	4	5	6	7	8	9	10	11	12	13	17	18	total
Amorphognathus sp. A						2										2
Ansella sp. A				1												1
Ansella sp. B									1	1					1	3
altoniodus sp. cf. *B. variabilis*		53	83	256												392
Besselodus semisymmetricus			1													1
Cornuodus longibasis				1											1	2
Dapsilodus mutatus				4	1	8	1	1	3	3		2	1	1	1	26
Drepanodus arcuatus				1	1											2
Hamarodus europaeus						12	6	12	5	9	5	9		2	4	64
Panderodus gracilis	3	8	4													15
Panderodus sp. A		1		1	1					1						4
Panderodus liripipus						2	2	1			2	1	2			10
Protopanderodus sp. A					1											1
Pygodus anserinus	2	2														4
Scabbardella altipes				13	3	37	36	47	22	24	14	35		7	12	256
Scabbardella sp. cf. *S. altipes*										1						1
Gen. et sp. Indet. 34			1													1
Gen. et sp. Indet. 35			1													1
total	5	64	88	279	7	61	45	61	31	39	21	47	3	10	25	786

Table 6. List of conodont species from the ST 2 section in the Satun area.
About 1.5 kg limestones were processed for each sample.

Satun area					
Section ST 2					
species / sample number	ST 20	21	22	23	total
Decoriconus fragilis			16		16
Oulodus sp. A	1				1
Ozarkodina excavata excavata	10	6	2	3	21
Panderodus langkawiensis	1	1			2
Pseudooneotodus beckmanni	1	2			3
total	13	9	18	3	43

Table 7. List of conodont species from the TAR 1 section in Tarutao Island.
About 1.5 kg limestones were processed for each sample.

Tarutao Island Section TAR 1													
sample number species	TAR 3	4	5	6	7	8	9	10	11	12	13	14	total
Acodus serierensis	2	1		6	6	1			2			1	19
Drepanodus arcuatus				1							3		4
Drepanoistodus concavus	8	1	1	10	3	1		1	4			3	32
Glyptoconus quadraplicatus		2											2
Monocostatus serierensis	1			4			1						6
Scolopodus trantistans	2	1											3
Teridontus nakamurai	3	2	2	5		3			1	2	2	1	21
Variabiloconus bassleri	11	5	1	15	10	14	2	1	3	2	2	4	70
total	27	12	4	41	19	19	3	2	10	4	7	9	157

Table 8. List of conodont species from the TAR 2 section in Tarutao Island.
About 1.5 kg limestones were processed for each sample.

Tarutao Island																											
Section TAR2																											
sample number / species	TAR 16	17	18	20	21	22	23	26	27	28	29	30	31	32	33	34	36	38	39	40	41	42	44	45	46	47	total
Acanthodus lineatus		1																									1
Acodus comptus																						2					2
Acodus serierensis						1	1										1	1									4
Colaptoconus bolites	1	2		2	2		1		4	2				2	1		4	2	2								25
Colaptoconus floweri	2	1	2	3		9																1	1		13		32
Colaptoconus quadraplicatus										2											2						4
Cornuodus longibasis																		1			1						2
Drepanodus arcuatus									1	1			1				3	1									7
Drepanoisotodus concavus						6	2		8				1	7			5	1									30
Drepanoistodus forceps																	3	3				2		3	15		26
Filodontus sp. cf. *F. filosus*																									4		4
Gen. et sp. Indet. 01							1																				1
Gen. et sp. Indet. 02																									1		1
Gen. et sp. Indet. 03																					2	2					4
Gen. et sp. Indet. 04									4																		4
Gen. et sp. Indet. 07																		1	6	1	12	3					23
Gen. et sp. Indet. 09													3	1	1	1											5
Gen. et sp. Indet. 10																									1		1
Gen. et sp. Indet. 11							1	1																			2
Gen. et sp. Indet. 17																									1		1
Gen. et sp. Indet. 18																									2		2
Gen. et sp. Indet. 19			1																								1
Gen. et sp. Indet. 4									4																		4
Parapanderodus striatus												1															1
Paroistodus sp. A																									1		1
Protoprioniodus yapu																						2					2
Rossodus manitouensis	3	1		2	2																						8
Scandodus sp. cf. *S. furnishi*																	4										4
Scolopodus sp. A																								1	20	1	22
Teridontus nakamurai	2	1		1	1	2			4				1		1												13
Variabiloconus bassleri	2	1	1			3	2		5		1						4										19
total	10	7	4	8	5	21	8	1	30	5	1	1	6	10	3	1	24	10	8	1	17	12	1	4	58	1	256

Table 9. List of Ordovician conodont species from the LAN 1 section in the Langkawi Islands.
About 1.5 kg limestones were processed for each sample.

Langkawi Islands																															
Section LAN 1 (Ordovician)																															
sample number / species	LAN 5	6	7	8	9	10	11	12	16	17	18	22	23	24	27	28	29	30	31	32	33	34	35	36	37	38	39	43	80	79	81	total
Amorphognathus sp. A																											5			5		10
Ansella jemtlandica				1	1	1									4	4			3		2								1	5		22
Aurilobodus leptosomatus														1																		1
Baltoniodus sp. cf. *B. variabilis*															23	100	15	120	64													322
Bergstroemognathus sp. A													2																			2
Cornuodus longibasis																		3												1		4
Dapsilodus mutatus																		3	2		6				2	1	1		10	25	3	53
Drepanoistodus costatus				2	3		1			1																						7
Hamarodus europaeus																						11	8	3	10	3	17		5	10		67
Panderodus gracilis															11	14	1	4			2		1				2		2	1		38
Panderodus nogamii		2	1	1		6	1	1	2				4	2																		20
Periodon sp. A											2	1	2	3																		8
Prioniodus amadeus				1		2	1							4																		8
Protopanderodus leonardii											1																					1
Protopanderodus liripipus																						2	2		1	2	2		3	2	3	17
Protopanderodus varicostatus															1																	1
Scabbardella altipes															2	1	1	11	32		16	1	17	1	17	3	4	1	16	26		149
Scolopodus multicostatus	1																															1
Scolopodus quadratus				1		1																										2
Triangulodus larapintinensis	1			2																												3
Gen. et sp. Indet. 12																			3	1	1											5
Gen. et sp. Indet. 13	3		1	1																												5
Gen. et sp. Indet. 20																					2	1										3
total	5	2	2	9	4	10	3	1	2	1	3	1	8	10	41	119	17	141	104	1	29	15	28	4	30	9	31	1	37	75	6	749

Table 10. List of Silurian conodont species from the LAN 1 section in the Langkawi Islands. About 1.5 kg limestones were processed for each sample.

	Langkawi Islands Section LAN 1 (Silurian)														
species / sample number	LAN 49	50	51	52	53	54	55	56	57	60	61	62	64	65	total
Belodella anomalis										5					5
Belodella devonica													73	62	135
Belodella resima								2	2						4
Dapsilodus hamari	47	28	28	19	22	19	12								175
Dapsilodus obliquicostatus			12	13	10	6	4								45
Dapsilodus praecipuus	3	1			1										5
Dapsilodus sparsus						6	4								10
Decoriconus fragilis	3									84	14	9		6	116
Flajsella sigmostygia														105	105
Flajsella sp .B														19	19
Flajsella sp A														37	37
Flajsella stygia														94	94
Gen. et sp. Indet. 05											6				6
Gen. et sp. Indet. 22														18	18
Oulodus sp. A		1								5		1		4	11
Ozarkodina ezcavata excavata								12	10	33	1	5	10	45	116
Ozarkodina remscheidensis eosteinhornensis													35		35
Ozarkodina remscheidensis remscheidensis								9	5			22			36
Panderodus langkawiensis	73	34	2		1										110
Panderodus sp. cf. *P. serratus*	64	28		3			2			2	1	1	4		105
Panderodus unicostatus	39	7	4	9	2	1				3	1	1	2		69
Pandorinellina sp. A													3		3
Pseudooneotodus beckmanni										10	8	2	135	1	156
Pseudooneotodus sp. A				3	1		2								6
Pterospathodus pennatus proceus	41	15													56
total	270	113	15	47	37	32	24	23	17	142	31	41	262	391	1445

Table 11. List of conodont species from the LAN 2 section in the Langkawi Islands. About 1.5 kg limestones were processed for each sample.

Langkawi Islands Section LAN 2						
species / sample number	LAN 70	75	76	77	78	total
Acodus sp. A			4	1		5
Acodus sp. cf. *A. deltatus*			5	2		7
Ansella sp. D				2		2
Aurilobodus leptosomatus			1			1
Bergstroemognathus sp. A	1					1
Cooperignathus aranda				2	1	3
Cornuodus longibasis				1		1
Drepanoistodus costatus				11		11
Gen. et sp. Indet. 21			2	1		3
Jumodontus gananda				1		1
Oelikodus sp. A	3					3
Panderodus nogamii			11	29	10	40
Protopanderodus varicostatus	1					1
Scolopodus multicostatus				15		15
Scolopodus quadratus		1	2	11		14
Triangulodus larapintinensis		2	3			5
total	5	3	28	76	11	123

Explanation of Plate 1

Figure 1-- Limestone exposure of the section III in the Thong Pha Phum area. Limestones of this area are partly covered by soil and commonly bedded and steeply dip.

Figure 2--Bedded limestone of the lowest rock unit of the section III in the Thong Pha Phum area.

Figure 3--Limestones of the highest unit of the section III in the Thong Pha Phum area. These limestones are thickly bedded and yield abundant macrofossils.

Plate 1

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Explanation of Plate 2

Figure 1-- High-angle cross laminations of the gray limestone of the section II in the Thong Pha Phum area.

Figures 2 and 3-- Black limestone of the highest part of the section III in the Thong Pha Phum area and nautiloids.

Plate 2

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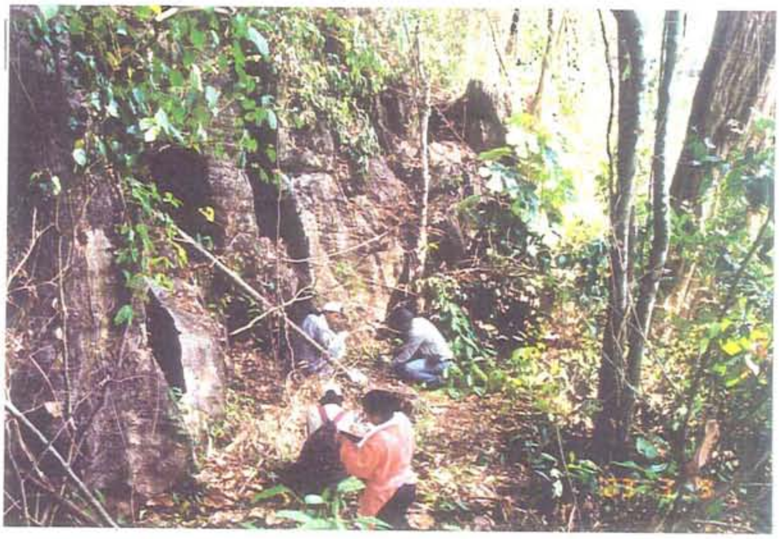
Explanation of Plate 3

Figure 1--Limestone exposure of the TUW 1 section in the Thung Wa area.

Figure 2-Gray limestone of the TUW 1 section in the Thung Wa area.

Figure 3--Limestone mountain in the Thung Wa area. This mountain shows the dip of the bedded limestone. The TUW 2 section is located along the base of this mountain.

Plate 3



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Explanation of Plate 4

Figure 1--A limestone exposure of the TUW 2 section in the Thung Wa area. Limestones of this area are partly covered by soil and commonly bedded and steeply dip.

Figure 2--Gray limestone of the upper part of the TUW 2 section.

Figure 3--Gray limestone of the middle part of the TUW 2 section.

Plate 4

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Explanation of Plate 5

Figure 1--A limestone mountain, covered by the jungle, in the Thung Song area. The TUS section is along a fissure of this mountain.

Figures 2 and 3--Gray limestone of the TUS section in the Thung Song area. The limestone with thin laminations alternates with the thickly bedded limestone.

Plate 5

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Explanation of Plate 6

Figure 1--Gray thin undulatory limestone of the lowest part of the ST 1 section in the Satun area.

Figure 2--Gray nodular limestone of the ST 1 section in the Satun area.

Figure 3--The bedding plane of the gray nodular limestone of the ST 1 section in the Satun area. The bedding surface is characterized by polygonal structures resembling mud cracks.

Plate 6

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Explanation of Plate 7

Figure 1--Gray nodular limestone of the ST 1 section in the Satun area. The marked stripes is made up of thin, dark colored layers.

Figure 2--Close-up of the red nodular limestone of the ST 1 section in the Satun area.

Figure 3--Exposure of the black shale of the uppermost part of the ST 1 section in the Satun area.

Plate 7

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Explanation of Plate 8

Figure 1--Graptolite shale of the ST 1 section in the Satun area. The white sticks printed on the surface of the shale are graptolites.

Figures 2 and 3--Exposure of the black shale of the uppermost part of the ST 2 section in the Satun area. This shale contains abundant tentaculites.

Plate 8

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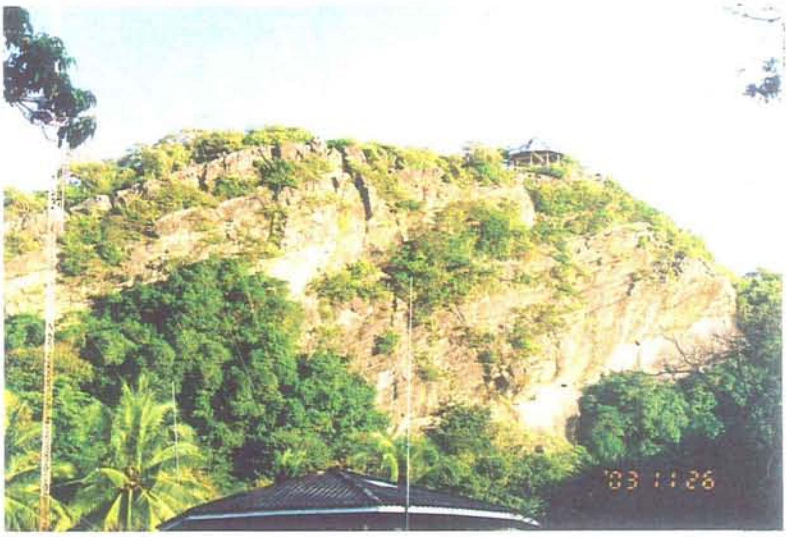
Explanation of Plate 9

Figure 1--A limestone mountain sited at northwest of Tarutao Island. This mountain shows the dip of the bedded limestone. The TAR 1 section is located along a path to the top of this mountain.

Figure 2--Bedded limestone of the lowermost part of the TAR 1 section in Tarutao Island.

Figure 3--Limestones of the middle part of the TAR 1 section in Tarutao Island. This limestone comprises gray massive limestone interbedded with brownish gray, thinly bedded limestones.

Plate 9



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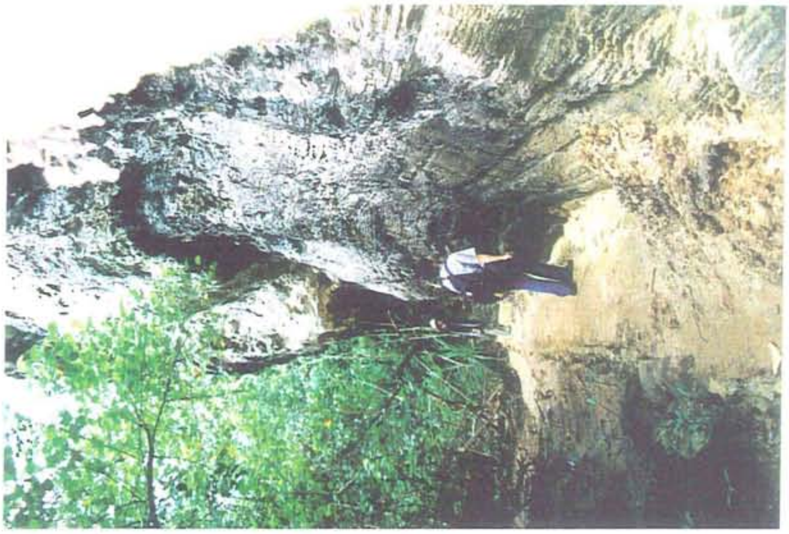

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Explanation of Plate 10

Figure 1--A view of the southern coast of Tarutao Island from the offing. The strata consisting the mountains dip about 30° to east.

Figure 2--Dark gray argillaceous limestone of the lowermost part of the TAR 2 section on Tarutao Island.

Figure 3--Exposure of the gray limestone overlying the argillaceous limestone in the TAR 2 section on Tarutao Island.

Plate 10

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Explanation of Plate 11

Figure 1--The upper part of the gray bedded limestone overlying the argillaceous limestone in the TAR 2 section on Tarutao Island.

Figures 2 and 3--Exposures of the interbeds of red to gray shale and gray limestone overlie the gray limestone sequence in the TAR 2 section on Tarutao Island.

Plate 11

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Explanation of Plate 12

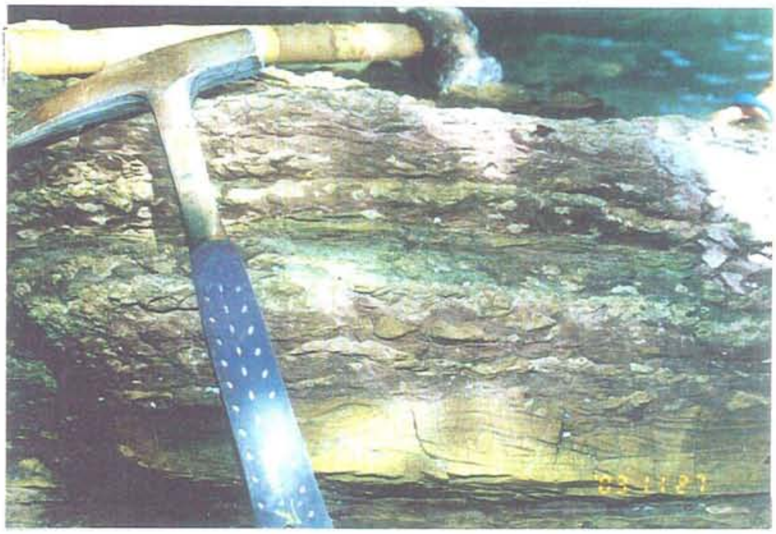
Figure 1-- Limestone alternated with red shale of the TAR 2 section on Tarutao Island.

Figure 2--Close-up of the interbeds of the red shale and gray limestone beds. The lower limestone shows the cross lamination.

Figure 3--Gray bedded limestone of the uppermost part of the TAR 2 section on Tarutao Island.

Plate 12

1



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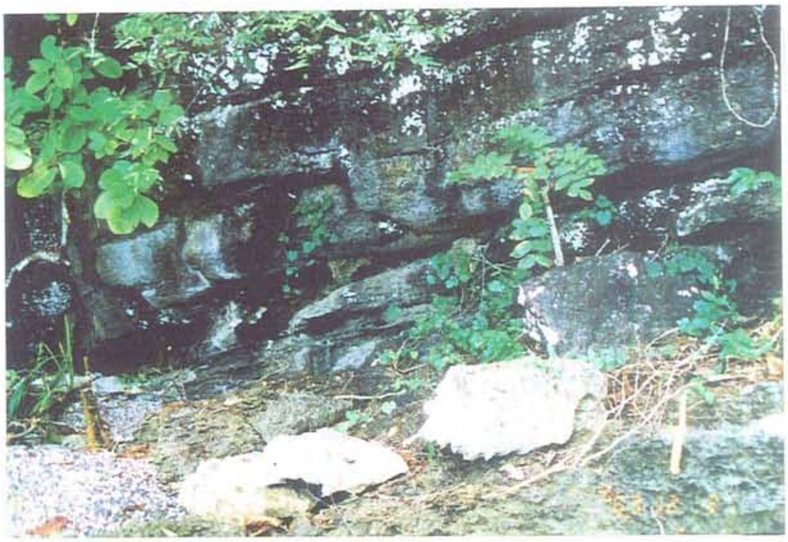
Explanation of Plate 13

Figure 1--Gray bedded limestone of the lowermost part of the Lower Setul Limestone of the LAN 1 section on Langkawi Islands.

Figure 2--The middle part of the Lower Setul Limestone of the LAN 1 section.

Figure 3--Limestone of the middle part of the Lower Setul Limestone of the LAN 1 section. These beds consist of the massive limestone, the cross-laminated limestone, and the limestone with the slumping structure.

Plate 13



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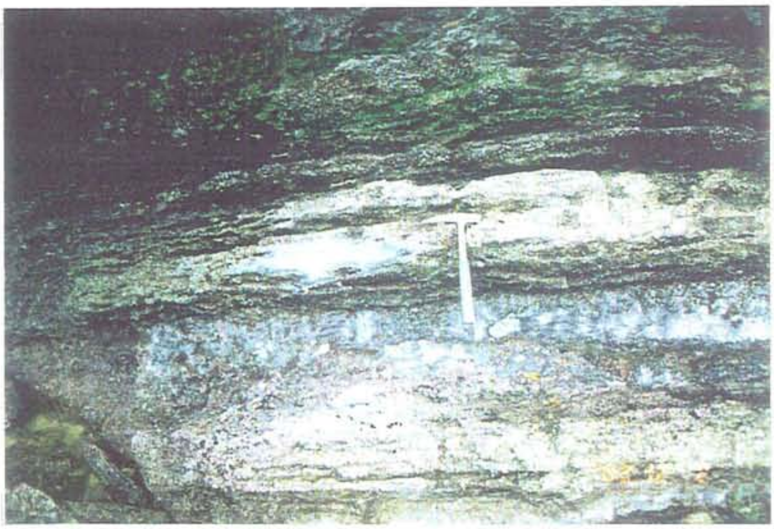

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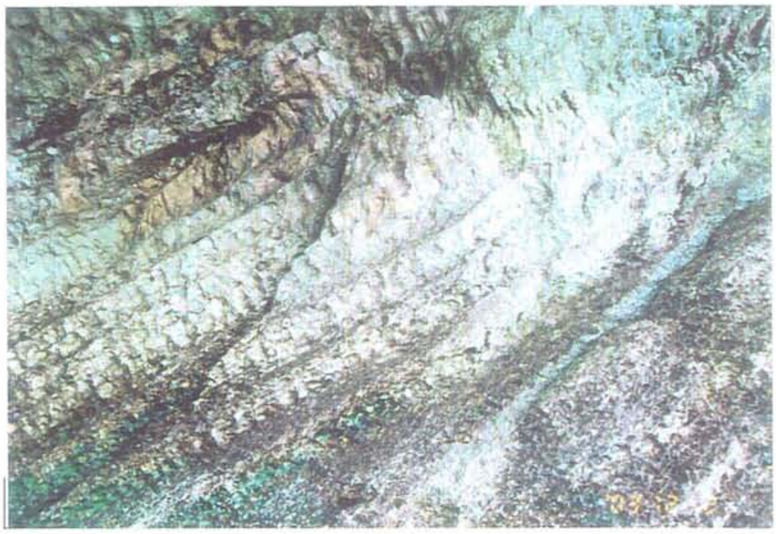
Explanation of Plate 14

Figures 1 and 2--Red nodular limestone of the Lower Setul Limestone of the LAN 1 section on Langkawi Islands. The marked stripes is made up of thin, dark colored layers.

Figure 3--The bedding plane of the red nodular limestone of the Lower Setul Limestone of the LAN 1 section on Langkawi Islands. The bedding surface is characterized by polygonal structures resembling mud cracks.

Plate 14



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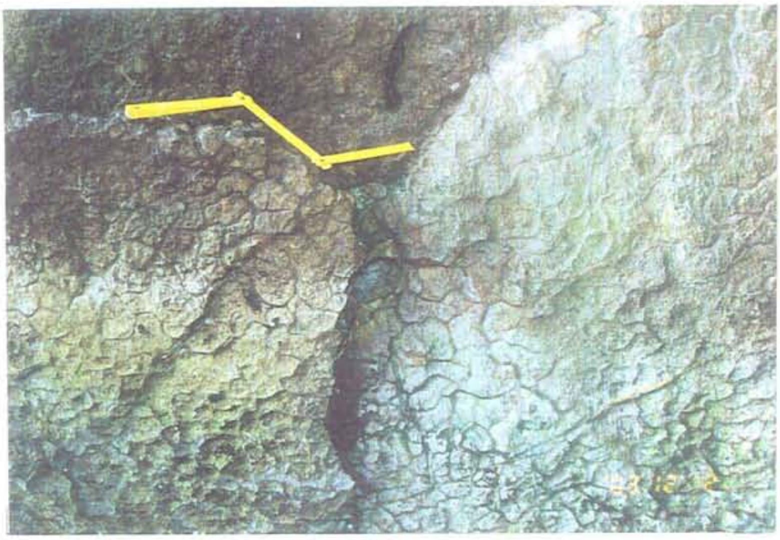

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Explanation of Plate 15

Figure 1-- Reddish gray limestone of the uppermost part of the Lower Setul Limestone of the LAN 1 section on Langkawi Islands.

Figure 2--The boundary of the Lower Setul Limestone and the black shale of the Lower Detrital Member of the LAN 1 section on Langkawi Islands. Fault clay, about 10 cm thick, is intercalated between the gray limestone and the black shale.

Figure 3--Black shale beds of the Lower Detrital Member of the LAN 1 section on Langkawi Islands.

Plate 15

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Explanation of Plate 16

Photographs of thin sections.

Figure 1--The upper part of the Lower Detrital Member of the LAN 1 section on Langkawi Islands. Gray limestones, which is back of the black shale beds, are the lowermost limestone of the Upper Setul Limestone of the LAN 1 section on Langkawi Islands.

Figures 2 and 3--Bedded gray limestone of the Upper Setul Limestone of the LAN 1 section on Langkawi Islands.

Plate 16

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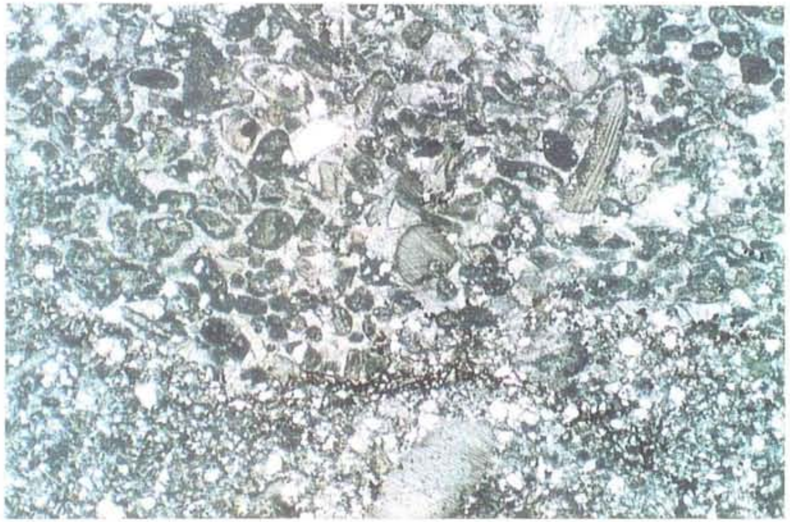
Explanation of Plate 17

Photographs of thin sections.

Figure 1--Pelletal oosparite in the lowermost part of the TPP section in the Thong Pha Phum area. This limestone mostly consists of unclear small ooids, peloids, coarse- to fine-grained quartz, and bioclasts with sparry calcite cement. Scale bar is 1 mm.

Figure 2--Arenaceous biosparite in the lowermost part of the TPP section in the Thong Pha Phum area. This limestone contains silt- to dominant fine-grained quartz and bioclasts with sparry calcite cement. Bioclasts of this picture include trilobites and bryozoans. Scale bar is 1 mm.

Figures 3 and 4--Lamination within arenaceous pelletal oosparite in the lower part of the TPP section in the Thong Pha Phum area. Silt-sized quartz grains, ooids, and peloids form laminations with sparry calcite cement. The median horizontal white layer of Figure 4 is an accumulation of quartz grains and the other parts mainly comprise ooids and peloids. Scale bars of Figures 3 and 4 indicates 10 mm and 1 mm, respectively.



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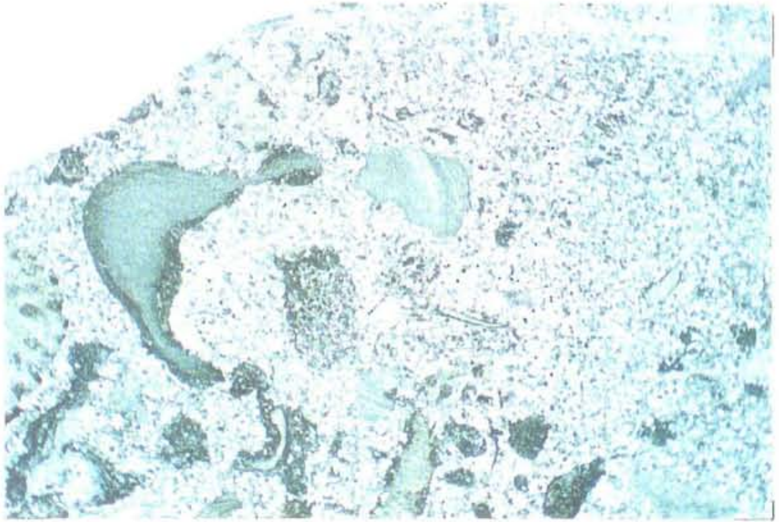

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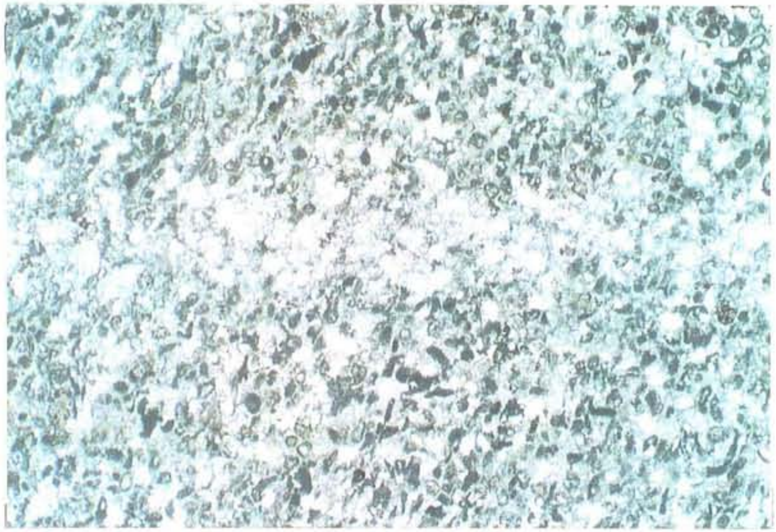


4

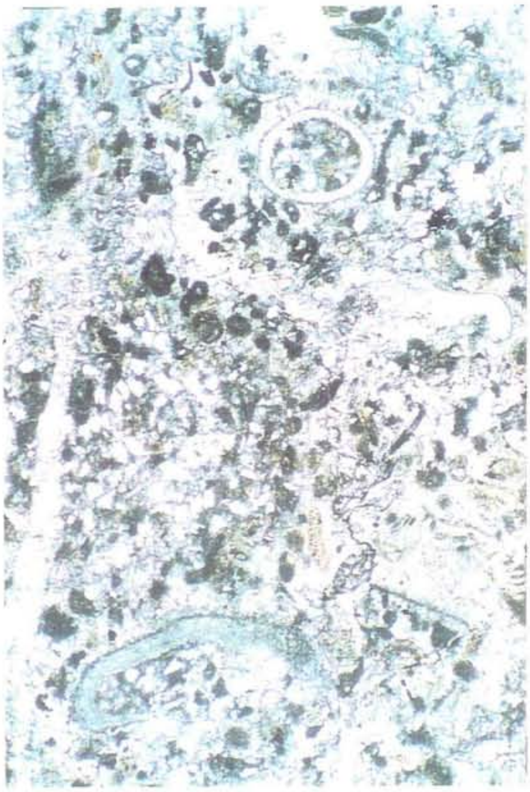
Plate 17

Explanation of Plate 18

Photographs of thin sections.

Figures 1 to 4--Arenaceous, oolitic, pelletal biosparite in the middle part of the TPP section in the Thong Pha Phum area. This limestone consists of peloids, silt-sized quartz grains, ooids, and various bioclasts within sparry calcite cements. Figure 4 is a crossed polar of Figure 3. Scale bars of Figures 1 and 2 are 1 mm, and 3 and 4 are 0.5 mm.

Plate 18



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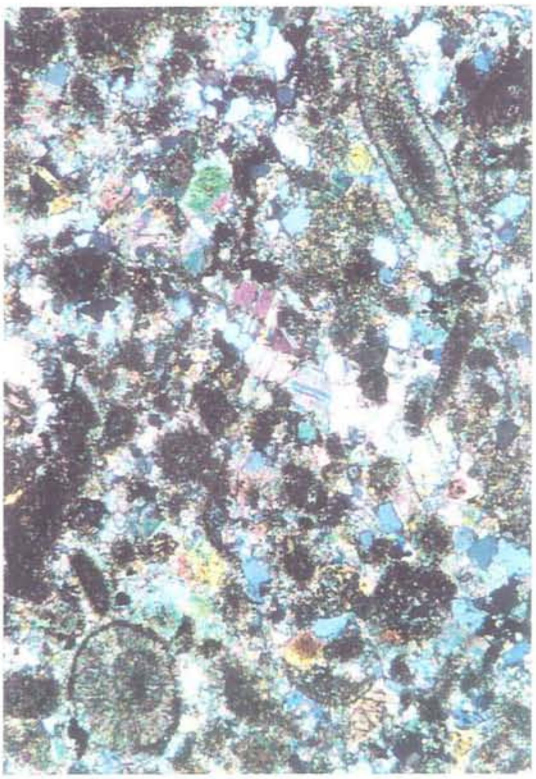

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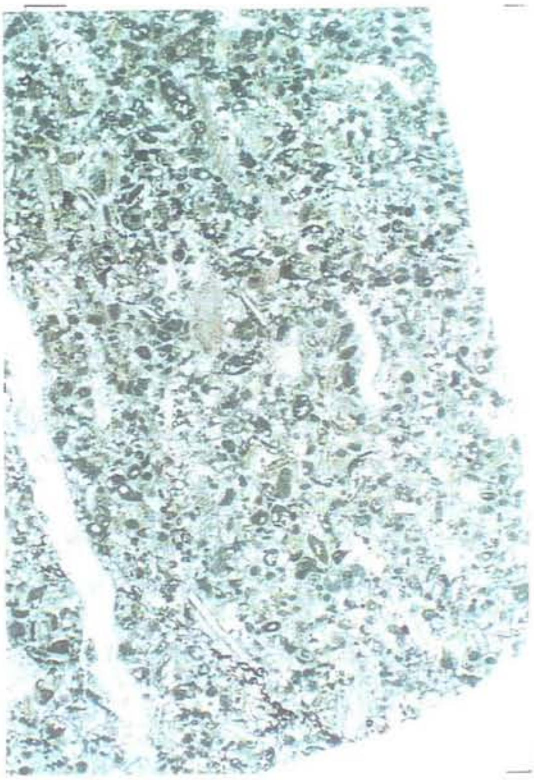

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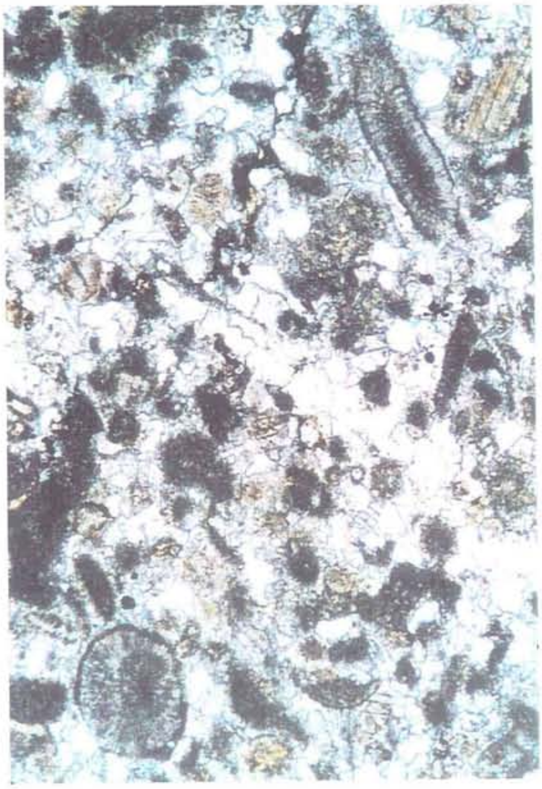


3

Explanation of Plate 19

Photographs of thin sections.

Figures 1 and 2--Biomicrite of the gray limestone in the upper part of the TPP section in the Thong Pha Phum area. This limestone composed of bioclasts, silt-sized quartz grains, and peloids within micritic matrices. Bioclasts include trilobites and shells. Scale bars are 1 mm.

Figures 3 and 4--Biomicrite of the black limestone in the uppermost part of the TPP section in the Thong Pha Phum area. This limestone comprises of bioclasts and small amount of silt-sized quartz grains within micritic matrices. Scale bars are 1 mm.

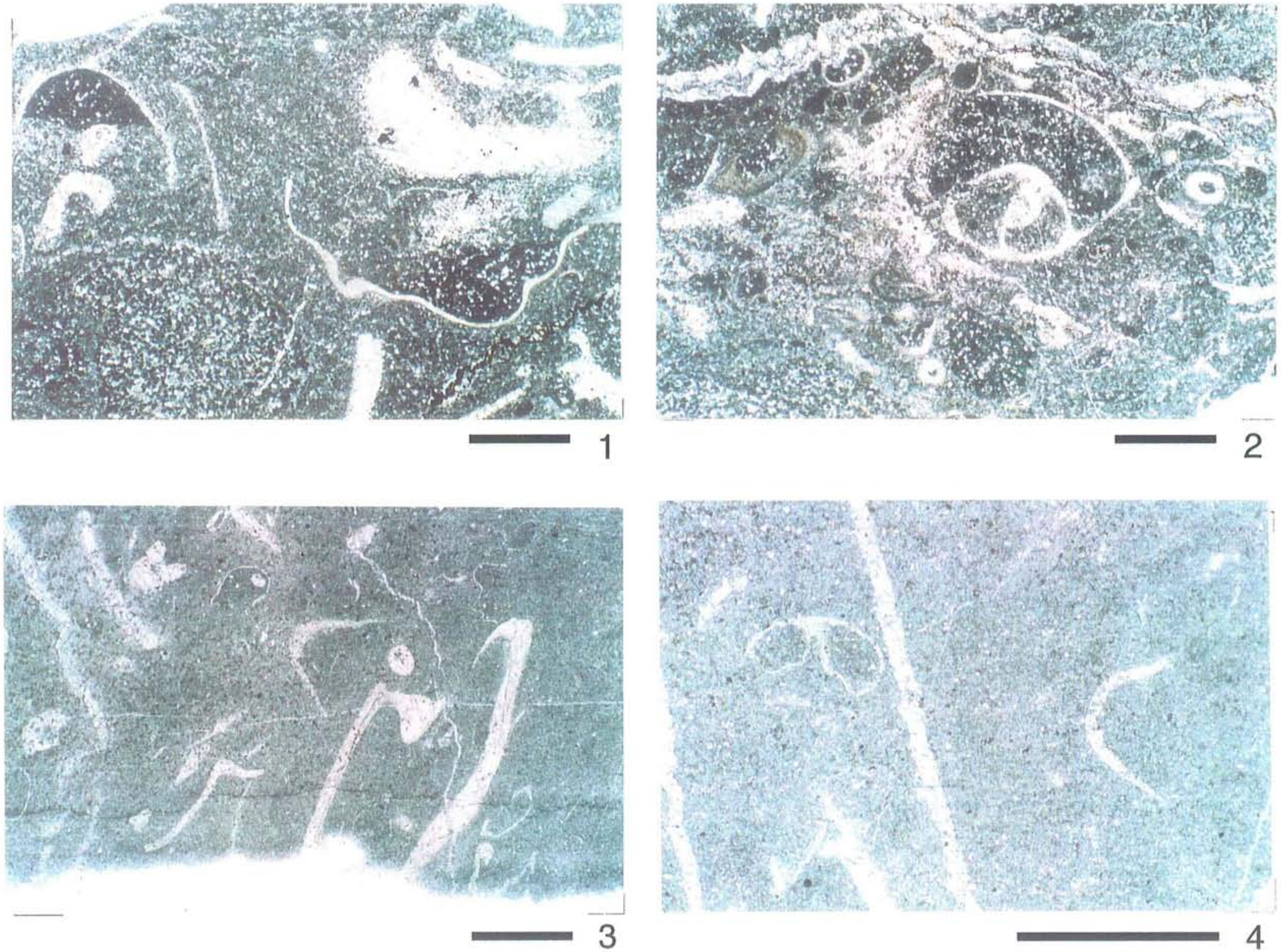


Plate 19

Explanation of Plate 20

Photographs of thin sections.

Figures 1 and 2--Lime mudstone collected from a thick limestone bed of the of the TUS section in the Thung Song area. This limestone contains silt-size to very fine-grained quartz within a micritic matrix. Figure 2 is a crossed polar of Figure 1. Scale bars are 0.5 mm.

Figures 3 and 4--Lime mudstone sampled from a thinly laminated limestone of the TUS section in the Thung Song area. Laminations consist of aggregations of silt-size to very fine-grained quartz grains. Figure 4 is a crossed polar of Figure 3. Scale bars are 0.5 mm.

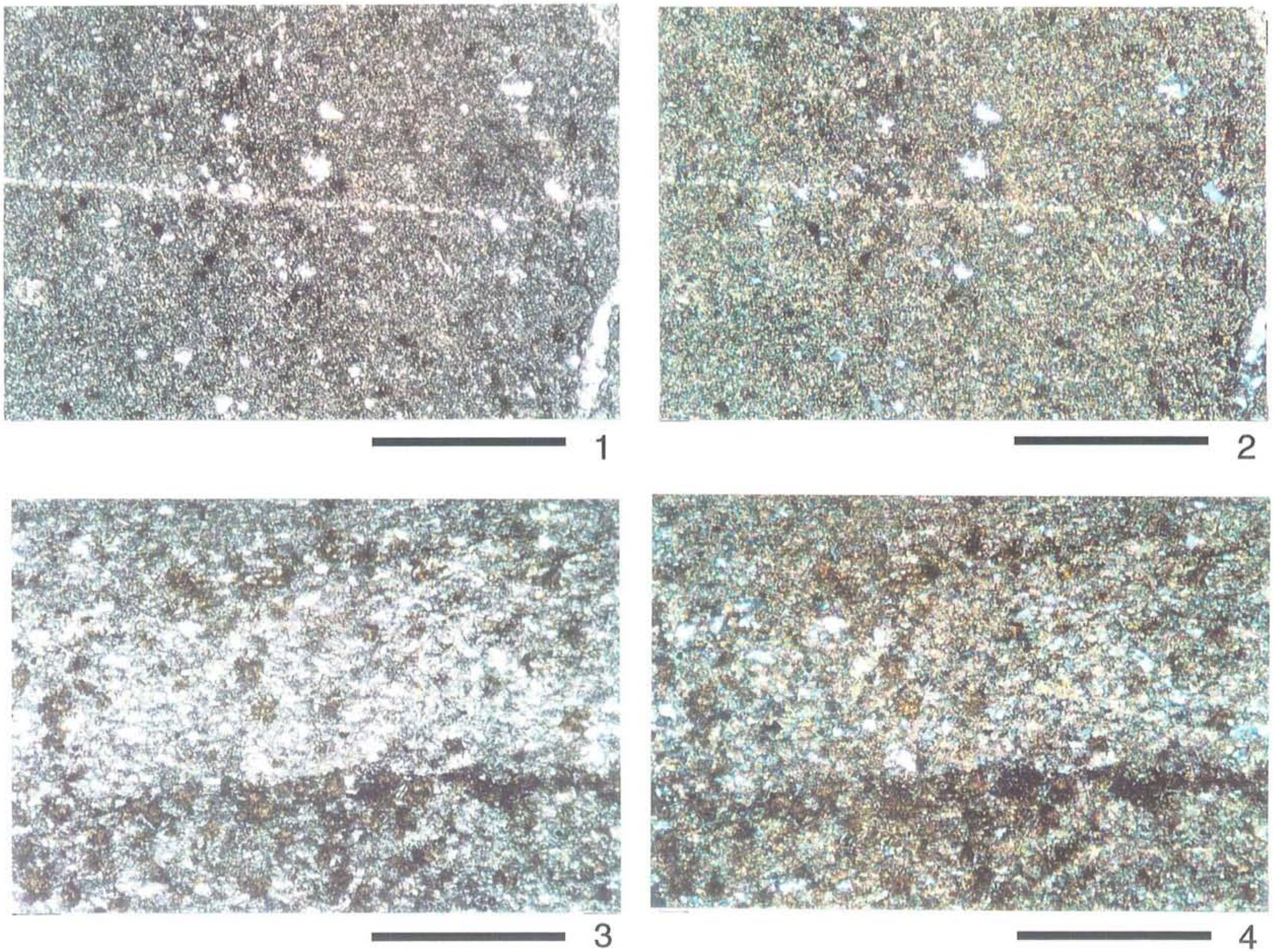


Plate 20

Explanation of Plate 21

Photographs of thin sections.

Figures 1 to 4--Fossiliferous micrite of the of the TUW 1 section in the Thung Wa area. This limestone includes bioclasts and silt-seized quartz grains in a micritic matrix. Figures 3 and 4 contain a fragment of trilobite. Figure 2 and 4 are crossed polar of Figure 1 and 3, respectively. Scale bars are 0.5 mm.

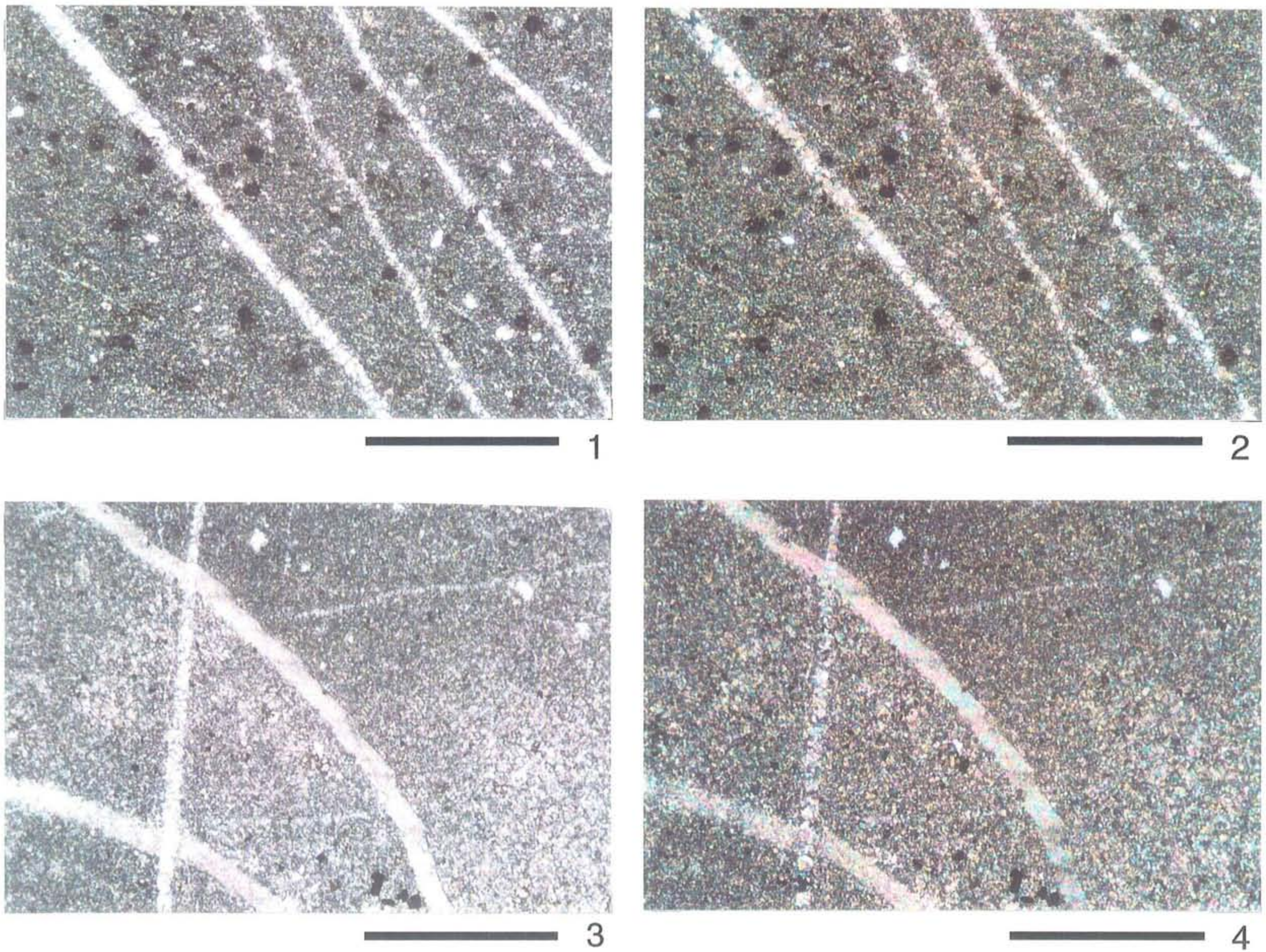


Plate 21

Explanation of Plate 22

Photographs of thin sections.

Figures 1 to 4--Fossiliferous micrite of the of the TUW 2 section in the Thung Wa area. This limestone includes bioclasts and silt-seized quartz grains in a micritic matrix. These figures contain shell fragments. Figures 3 and 4 show a stylolitic texture. Figure 2 and 4 are crossed polar of Figure 1 and 3, respectively. Scale bars are 0.5 mm.

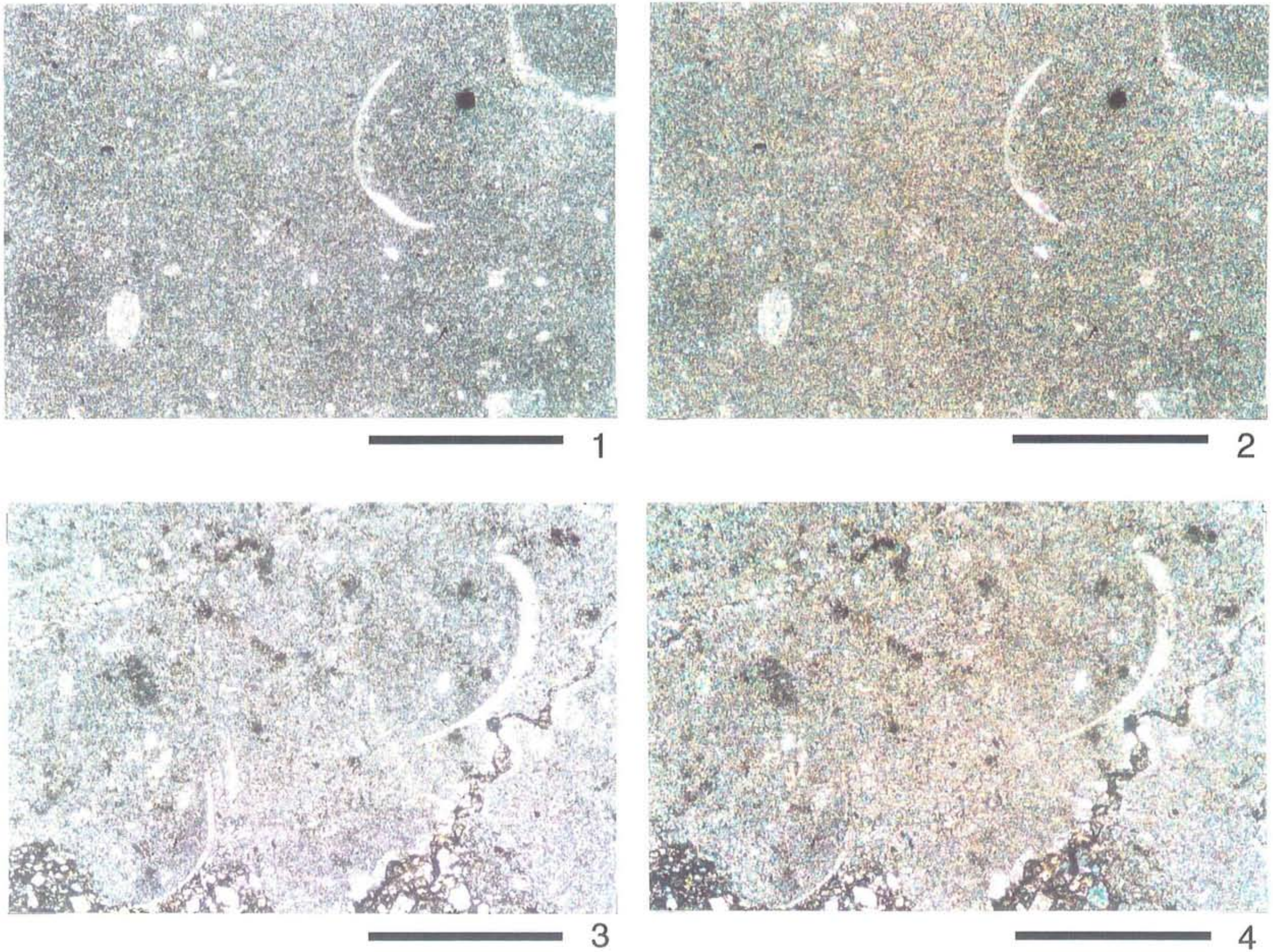
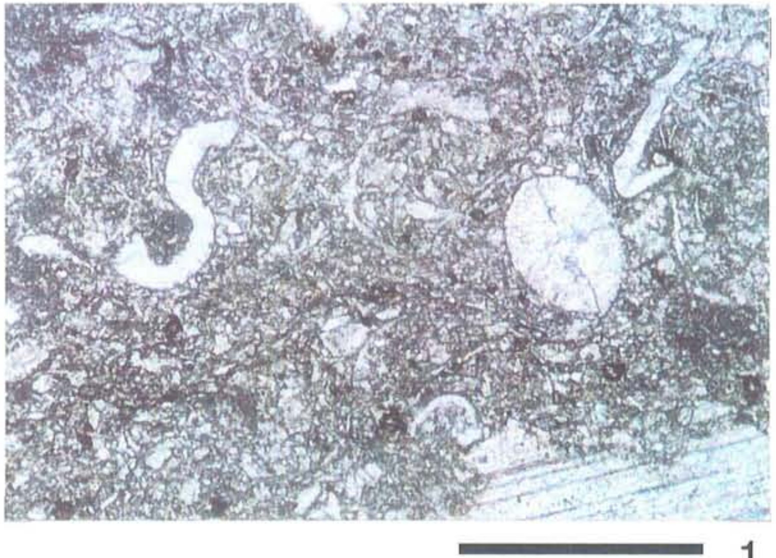


Plate 22

Explanation of Plate 23

Photographs of thin sections.

Figures 1 to 4--Biomicrite of the gray thin undulatory limestone of the lowermost part of the ST 1 section in the Satun area. These pictures show ostracods, fragments of trilobites, and unidentified thin shells within micritic matrices. Figure 2 and 4 are crossed polar of Figure 1 and 3, respectively. Scale bars are 0.5 mm.



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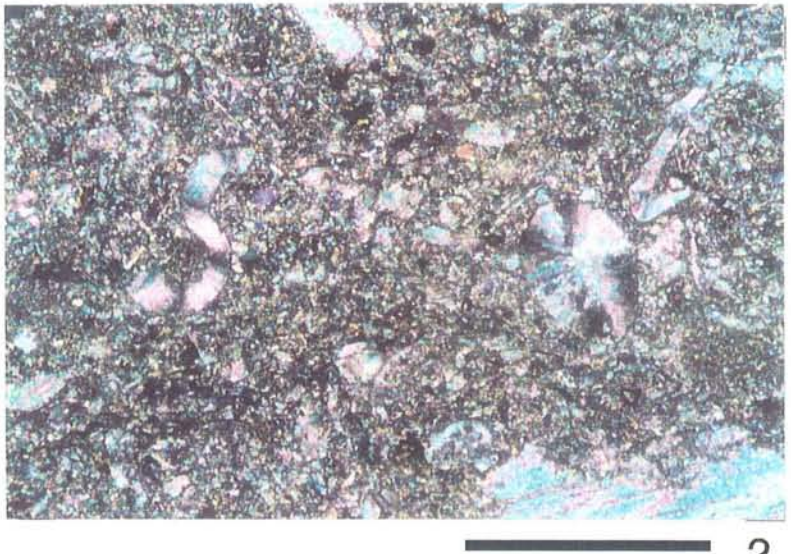

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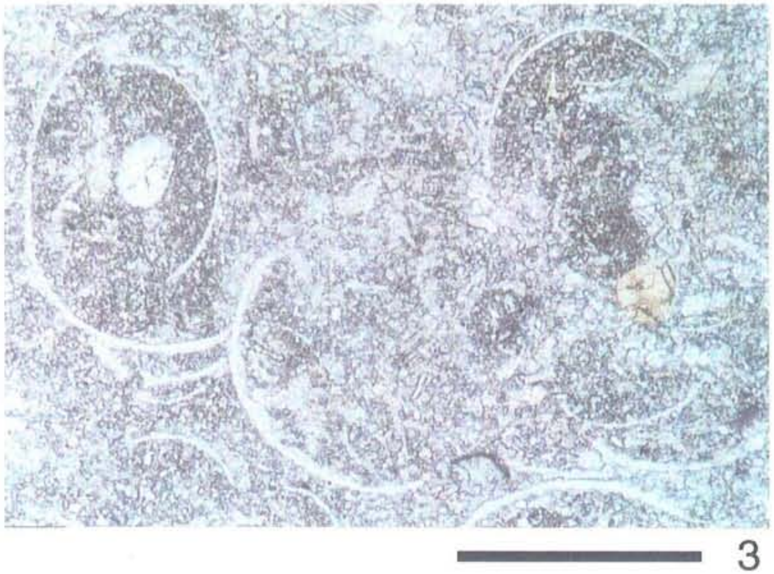

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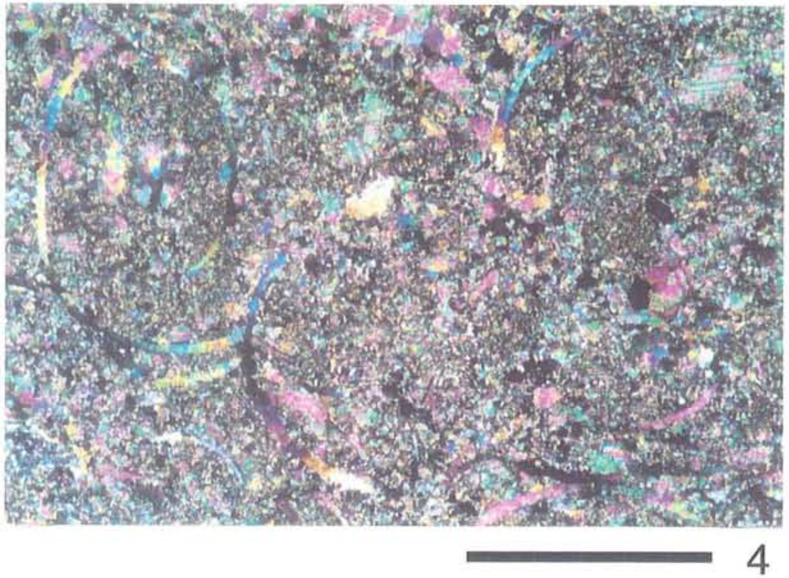


4

Plate 23

Explanation of Plate 24

Photographs of thin sections.

Figures 1 and 2--Biomicrite of the gray to yellowish nodular limestone of the middle part of the ST 1 section in the Satun area. This limestone consists of abundant and various bioclasts in micritic matrices. Bioclasts showed by these pictures are trilobites and small thin shells. Figure 2 is crossed polar of Figure 1. Scale bars are 0.5 mm.

Figures 3 and 4--Biomicrite of the red nodular limestone of the upper part of the ST 1 section in the Satun area. This limestone consists of abundant and various bioclasts in micritic matrices. Bioclasts showed by these pictures are gastropods, trilobites, and small thin shells. Figure 4 is crossed polar of Figure 3. Scale bars are 0.5 mm.

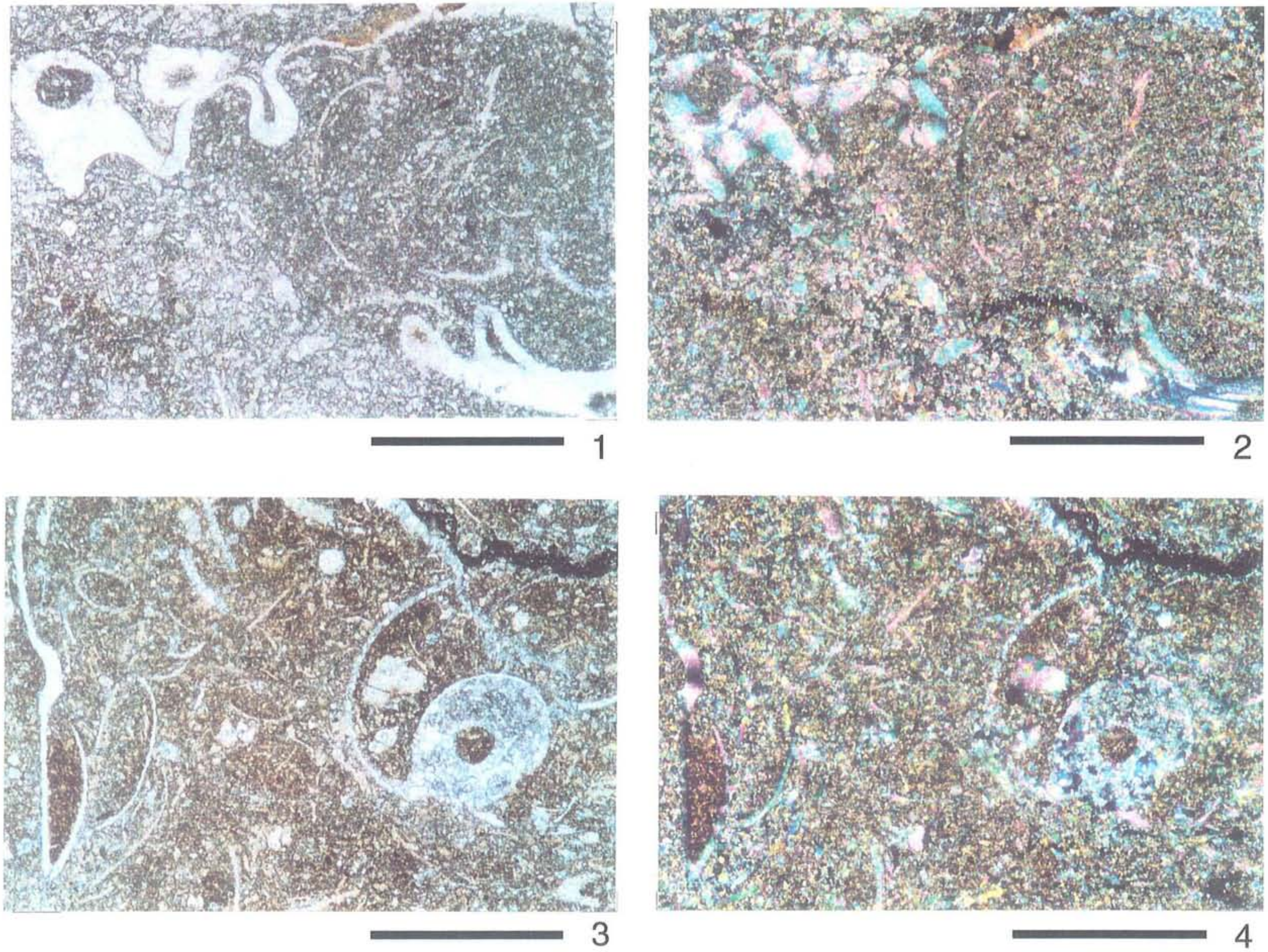


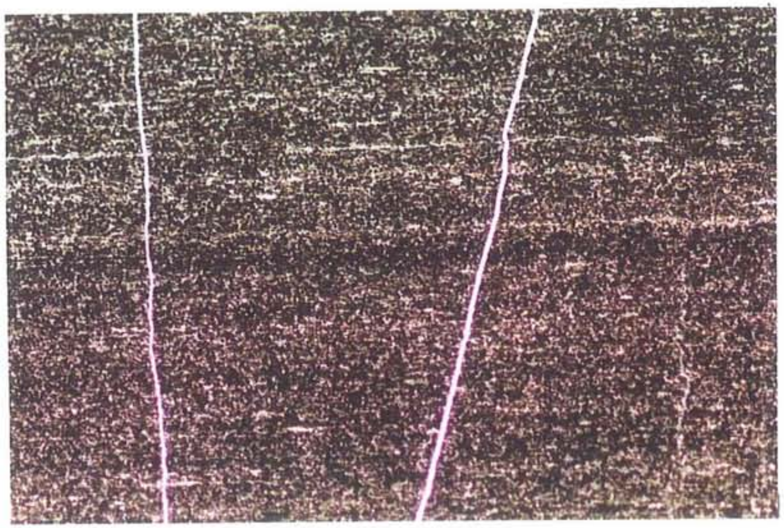
Plate 24

Explanation of Plate 25

Photographs of thin sections.

Figures 1 and 2--Black shale of the uppermost part of the of the ST 1 section in the Satun area. This shale consisting of clay minerals and silt-sized quartz grains. Small sponge fragments are contained. Scale bars of Figures 1 and 2 are 5 mm and 0.1 mm, respectively.

Figures 3 and 4--Biomicrite in the ST 2 section in the Satun area. These pictures include abundant ostracods within micritic matrices. Scale bars are 1 mm.



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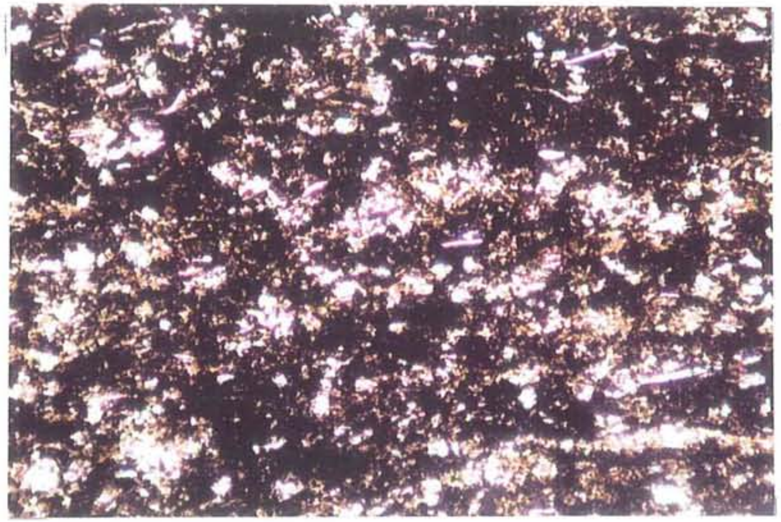

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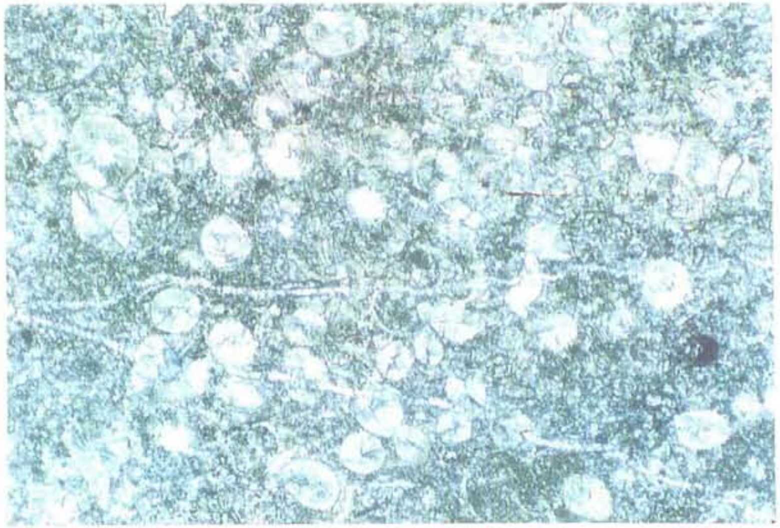


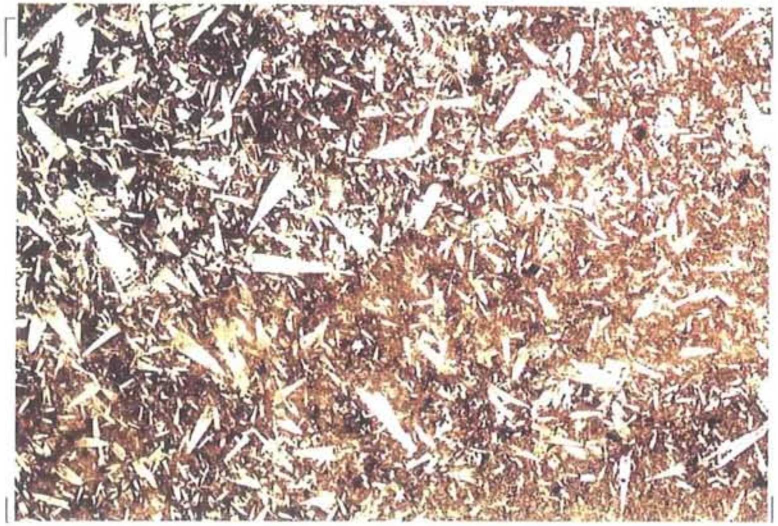
4

Plate 25

Explanation of Plate 26

Photographs of thin sections.

Figures 1 to 4--Black shale of the uppermost part of the of the ST 2 section in the Satun area. Figures 1 and 3 are the vertical sections and 2 and 4 are the parallel sections to a bedding plane. This limestone consists of quartz grains less than a silt size, clay minerals, and black organic matter. Many small, triangular shells of tentaculite are also contained. Scale bars of Figures 1 and 2 are 10 mm, and Figures 3 and 4 are 1 mm.



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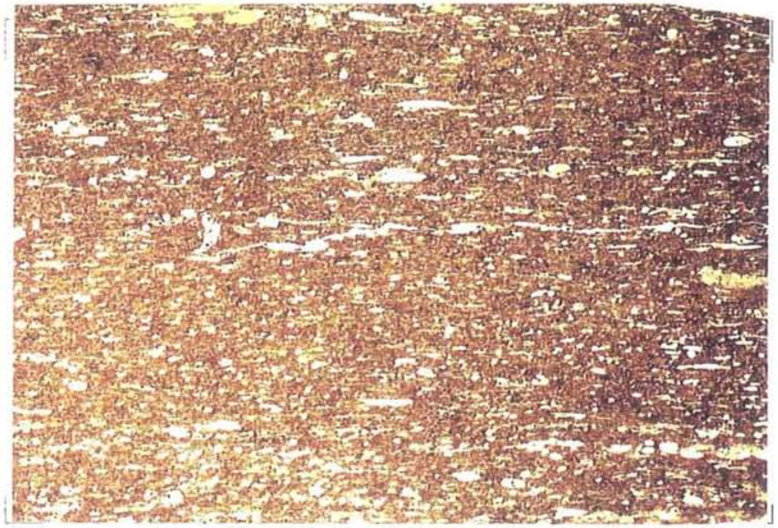

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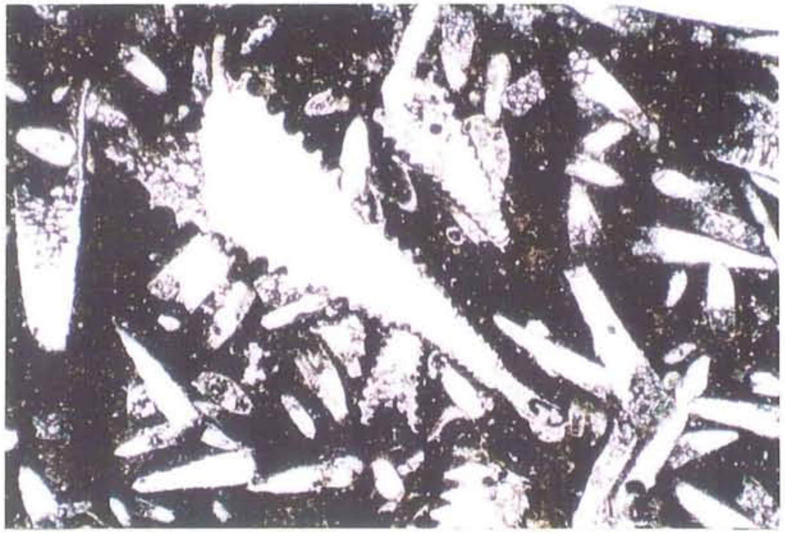

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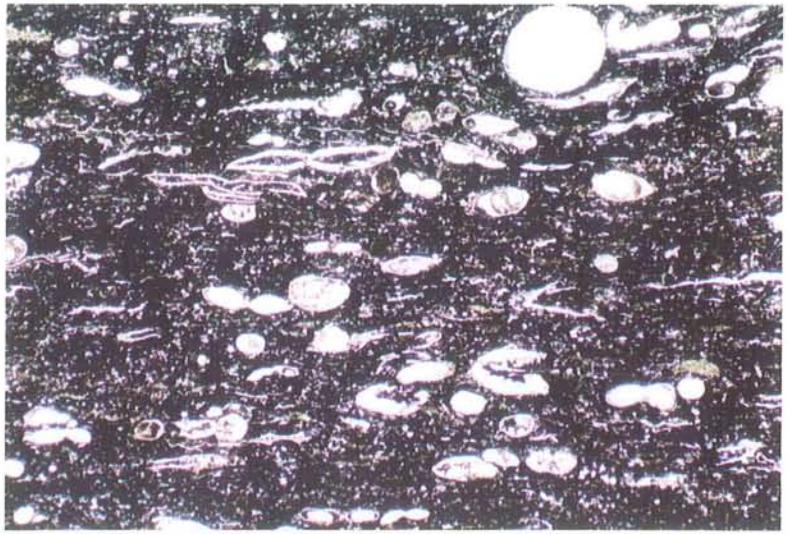


4

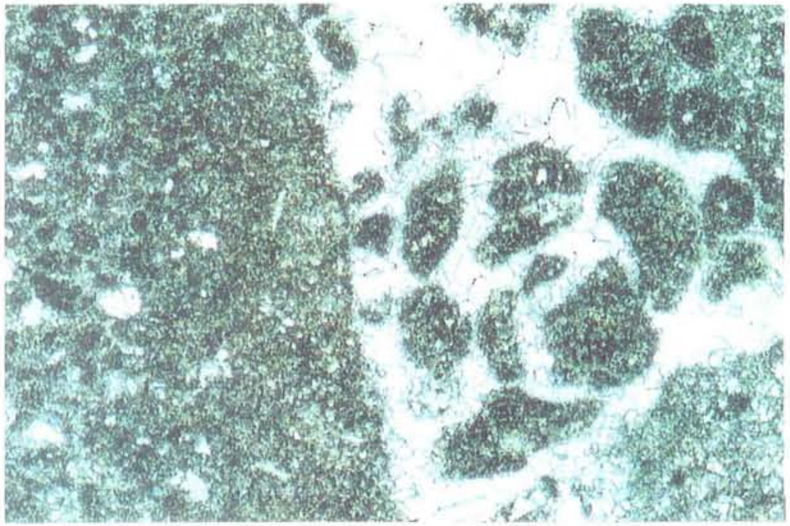
Plate 26

Explanation of Plate 27

Photographs of thin sections.

Figures 1 and 2--Pelsparite of the lower limestone of the TAR 1 section on Tarutao Island. This limestone contains abundant peloids and small amount of lump, and silt-sized quartz grains in sparry calcite cement. Figure 2 is crossed polar of Figure 1. Scale bars are 0.5 mm.

Figures 3 and 4--Oosparite of the upper limestone of the TAR 1 section on Tarutao Island. This limestone consists of ooids, lump, and small amount of peloids and silt-sized quartz within sparry calcite cement. Figure 4 is crossed polar of Figure 3. Scale bars are 0.5 mm.



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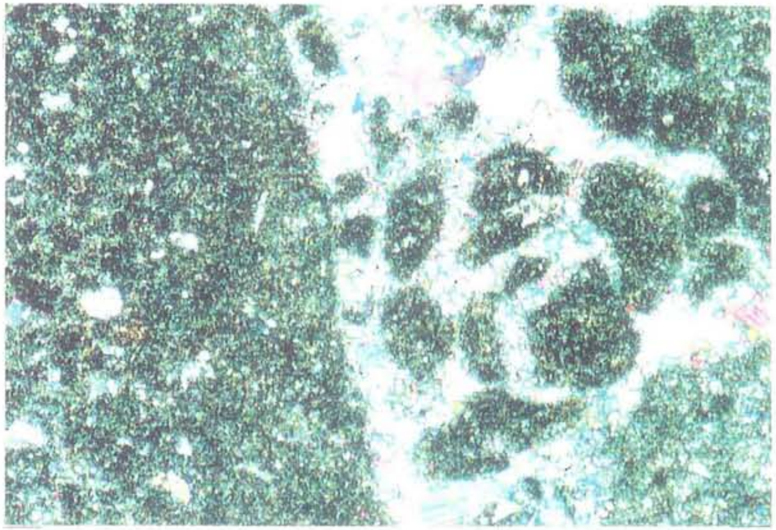

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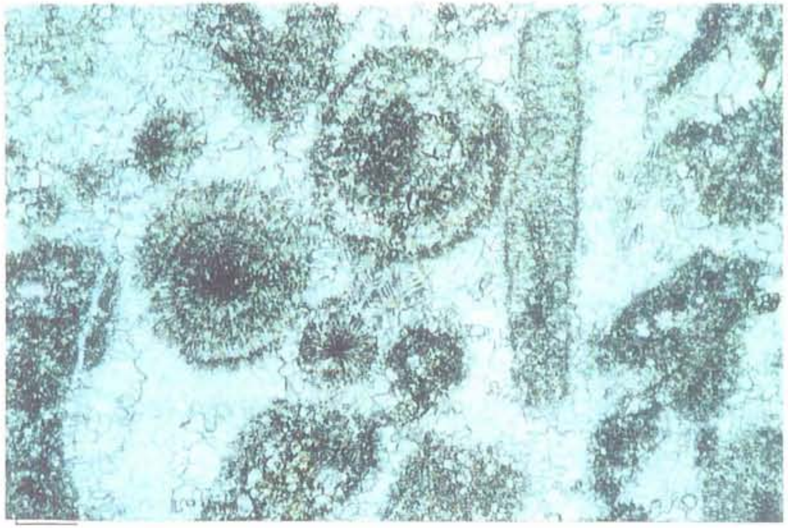

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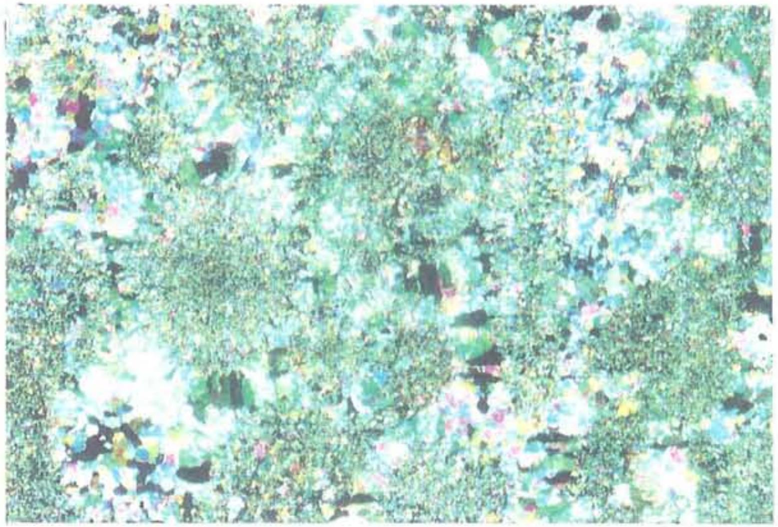


4

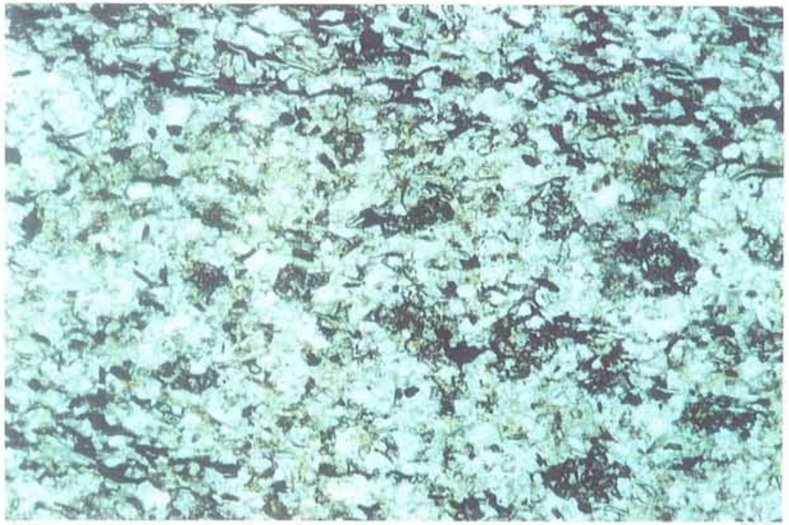
Plate 27

Explanation of Plate 28

Photographs of thin sections.

Figures 1 and 2--Red shale in the interbeds of shale and limestone of the TAR 2 section on Tarutao Island. This shale is calcareous mudstone and consists of silt-sized quatz and calcite grains and partly contains fine sand-sized grains. Figure 2 is crossed polar of Figure 1. Scale bars are 0.5 mm.

Figures 3 and 4--Limestone in the interbeds of shale and limestone of the TAR 2 section on Tarutao Island. This limestone is biomicrite and includes quartz grains and bioclasts. Figure 4 is crossed polar of Figure 3. Scale bars are 0.5 mm.



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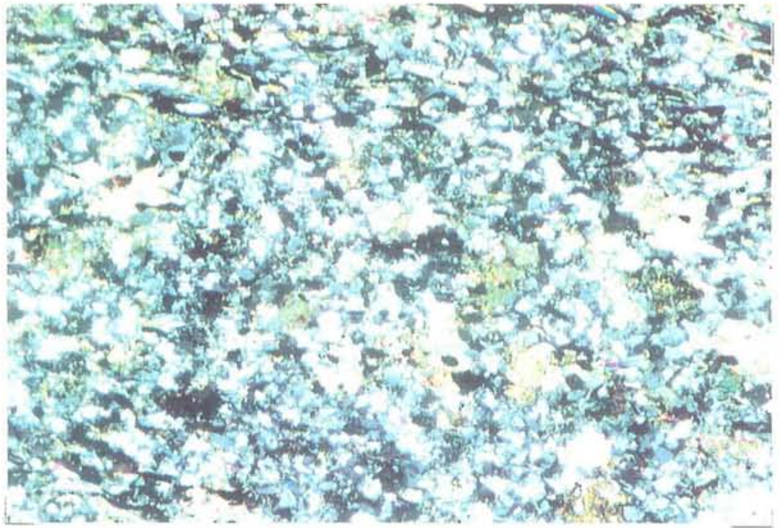

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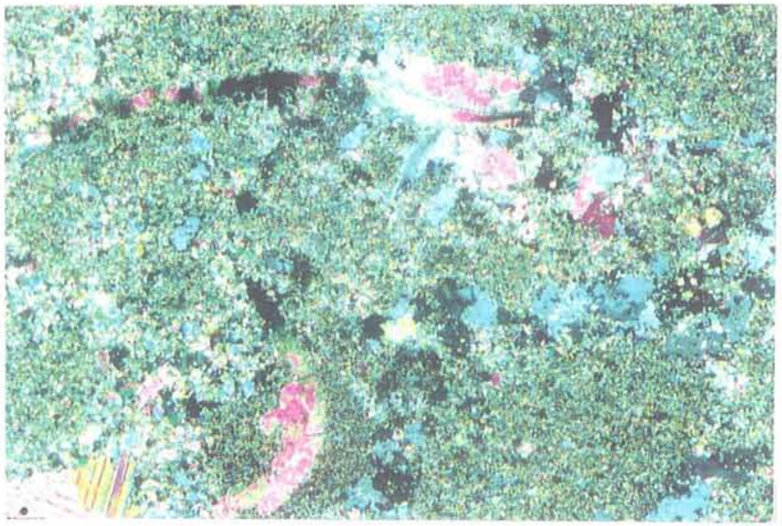


4

Plate 28

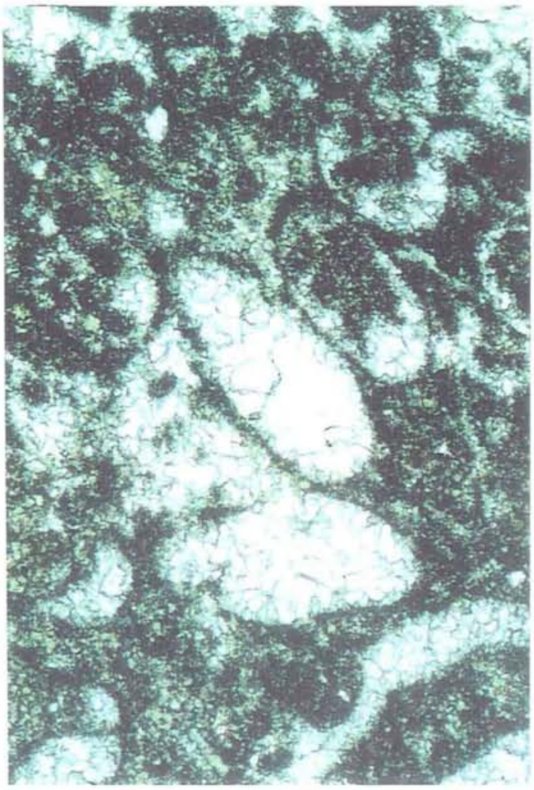
Explanation of Plate 29

Photographs of thin sections.

Figures 1 and 2--Biomicrite in the lower part of the Lower Setul Limestone of the LAN 1 section on Langkawi Islands. This limestone comprises peloids, bioclasts, and silt-sized quartz grains in micritic matrix. Figure 2 is crossed polar of Figure 1. Scale bars are 0.5 mm.

Figures 3 and 4--Biomicrite of the gray to red nodular limestone in the Lower Setul Limestone of the LAN 1 section on Langkawi Islands. This limestone consists of abundant and various bioclasts in micritic matrices. Bioclasts showed by these pictures are ostracods and unidentified thin shells. Figure 4 is crossed polar of Figure 3. Scale bars are 0.5 mm.

Plate 29



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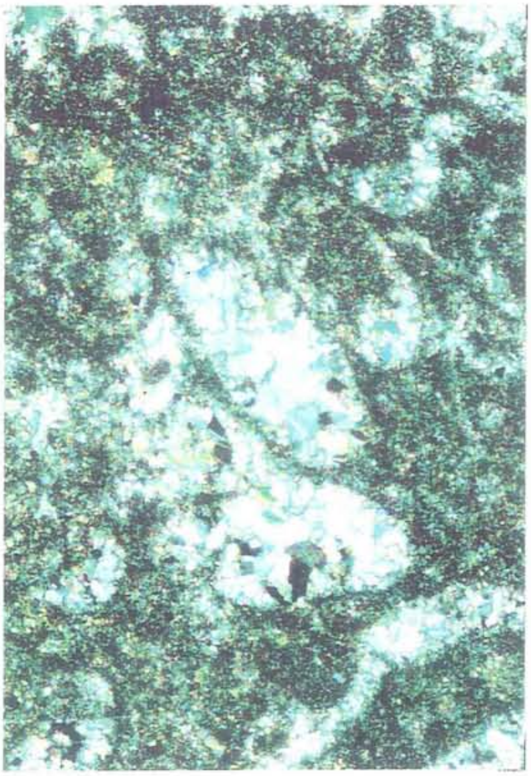

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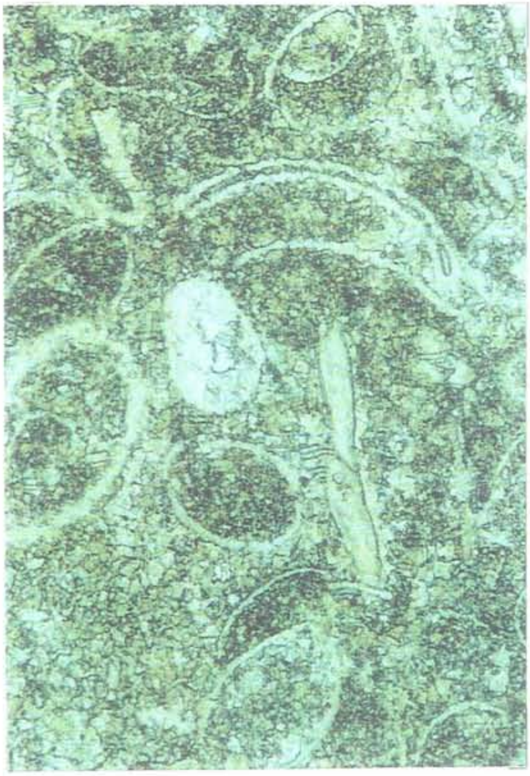

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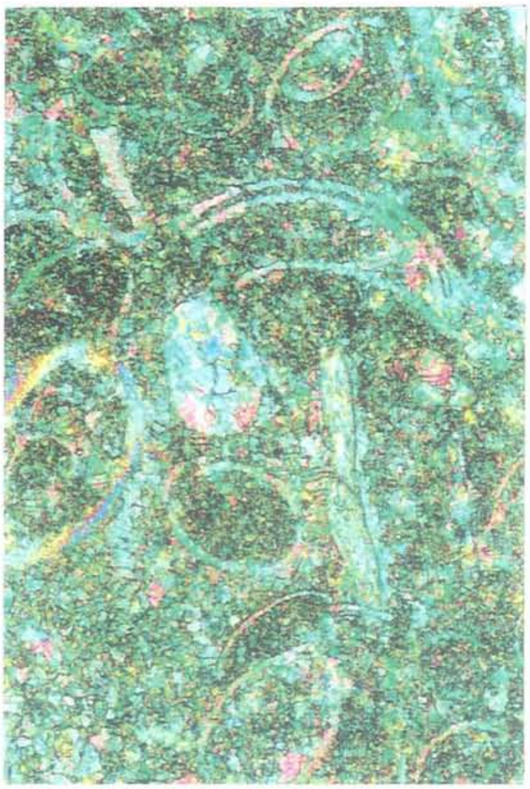


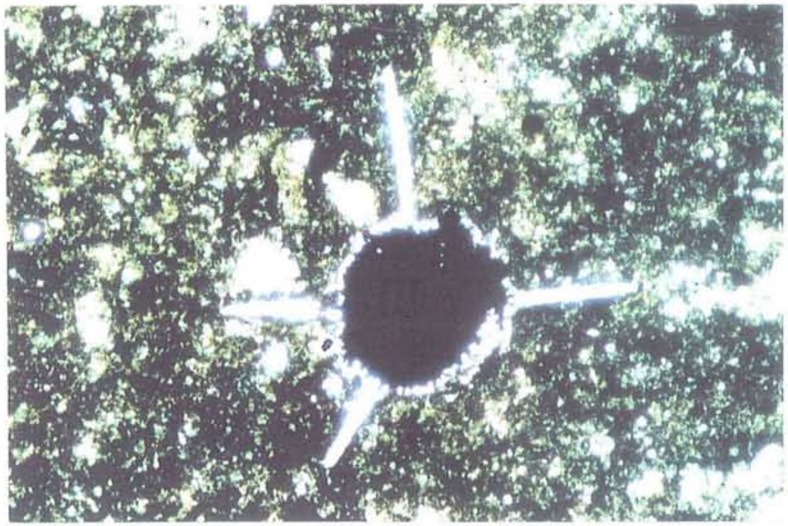
4

Explanation of Plate 30

Photographs of thin sections.

Figures 1 and 2--Black shale of the Lower Detrital Member of the of the LAN 1 section on the Langkawi Islands. This shale consisting of clay minerals and silt-sized quartz grains. Radiolarians are contained. Scale are 0.5 mm.

Figures 3 and 4--Biomicrite of the Upper Setul Limestone of the LAN 1 section on the Langkawi Islands. These pictures include ostracods and thin unidentified shells within micritic matrices. Scale bars are 0.5 mm.



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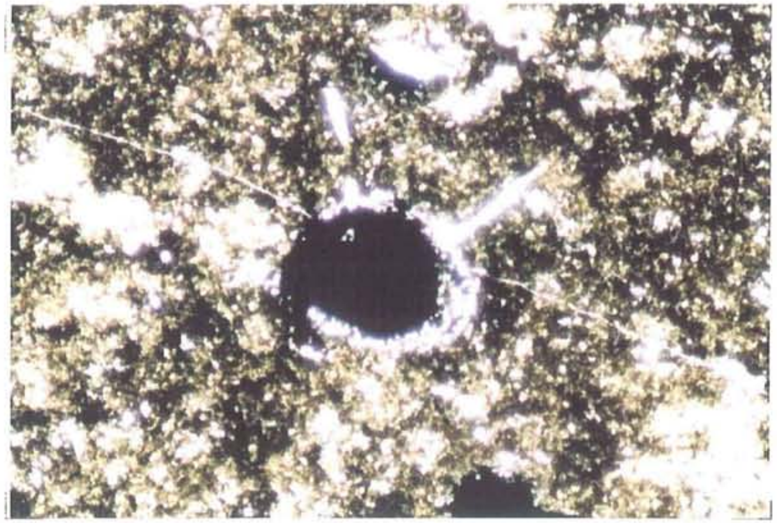

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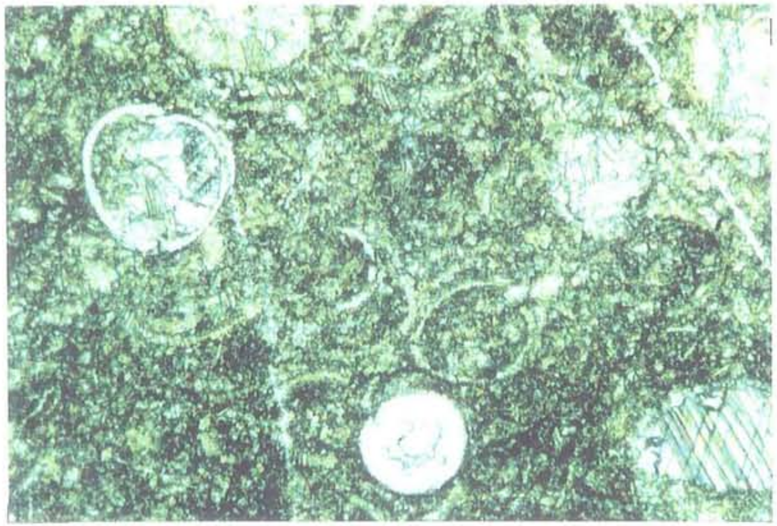

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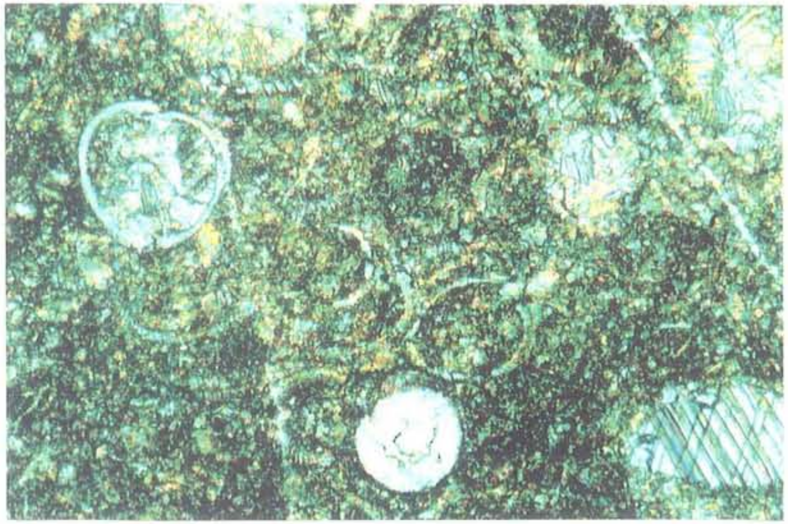


4

Plate 30

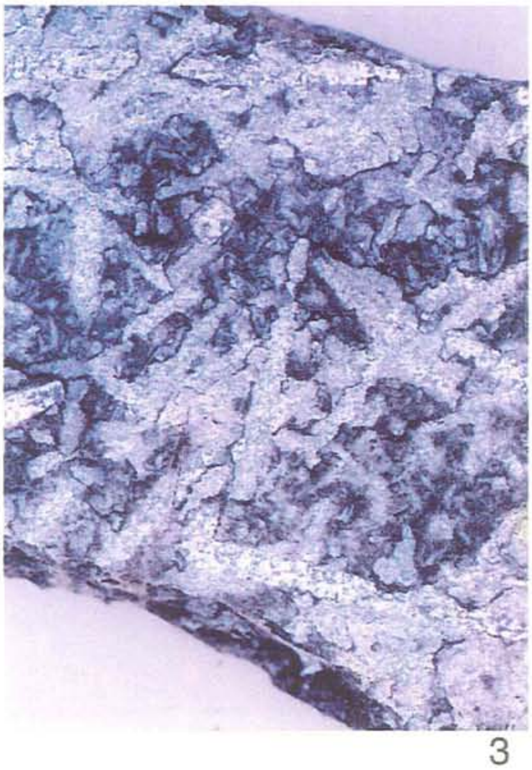
Explanation of Plate 31

Figures 1 to 4--Mode of occurrence of graptolite-bearing shale. White sticks are graptolite fossils. Scale bar is 1 mm.

Plate 31

1

2



3

4

Explanation of Plate 32

Photographs of graptolites. Scale bar indicates 5 mm.

Figures 1 to 10--*Normalograptus pseudovenustus pseudovenustus* (Legrand, 1986)

1, IGUT-ag0007, sample G.

2, IGUT-ag0006, sample G.

3, IGUT-ag0002, sample G.

4, IGUT-ag0001, sample G.

5, IGUT-ag0011, sample G.

6, IGUT-ag0015, sample G.

7, IGUT-ag0038, sample G.

8, IGUT-ag0035, sample G.

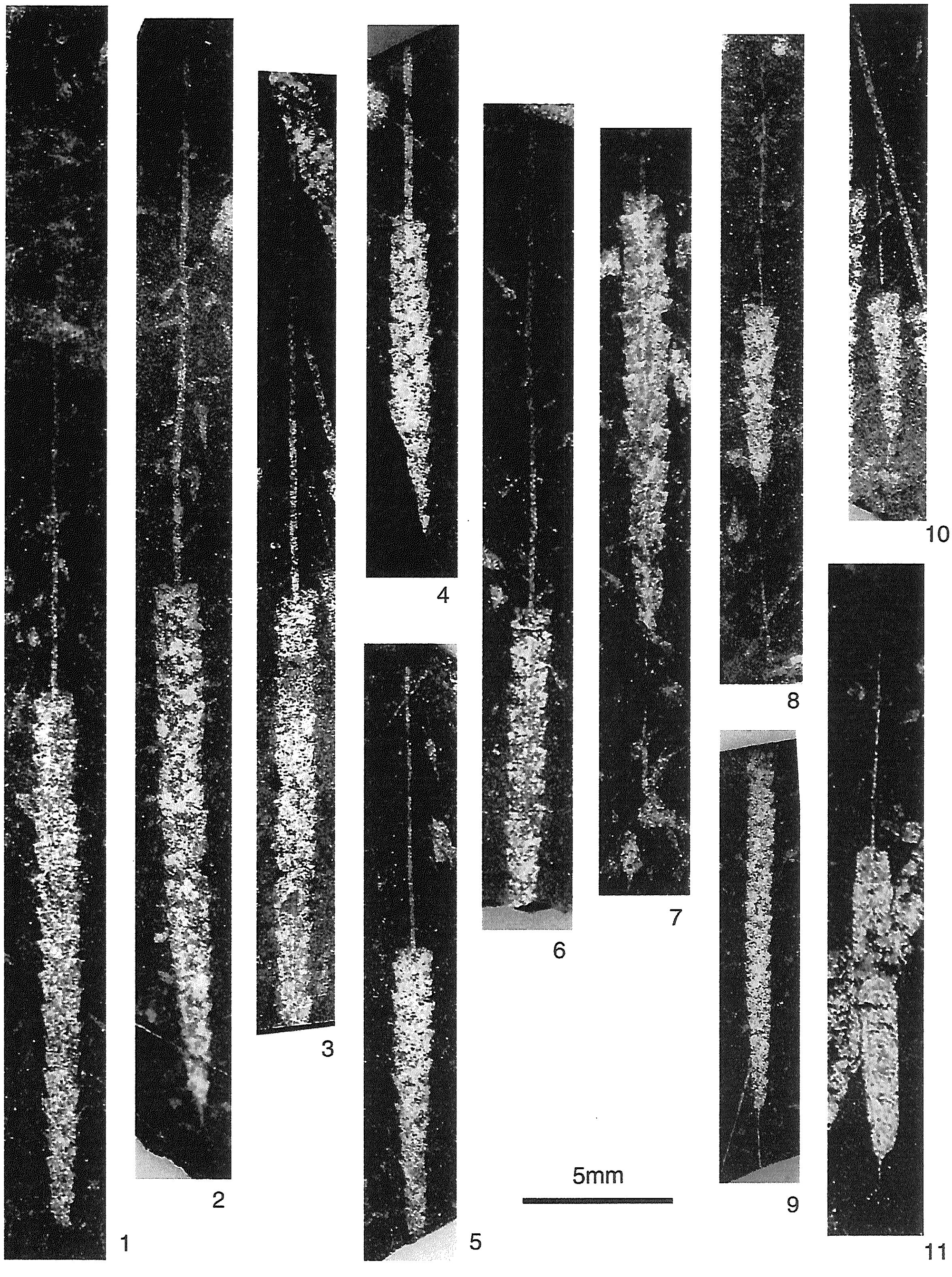
9, IGUT-ag0028, sample G.

10, IGUT-ag0013, sample G.

Figure 11--*Normalograptus* sp.

11, IGUT-ag0002, sample G.

Plate 32



Explanation of Plate 33

Photographs of isolated tentaculite specimens. All figures are digital images of scanning electron microscope. Scale bar indicates 500 μm.

Figures 1 to 15--*Nowakia acuaria* (Richter, 1854)

1, IGUT-ag00652, sample T.

7, IGUT-ag0056, sample T.

8, IGUT-ag0053, sample T.

9, IGUT-ag0062, sample T.

10, IGUT-ag0061, sample T.

11, IGUT-ag0051, sample T.

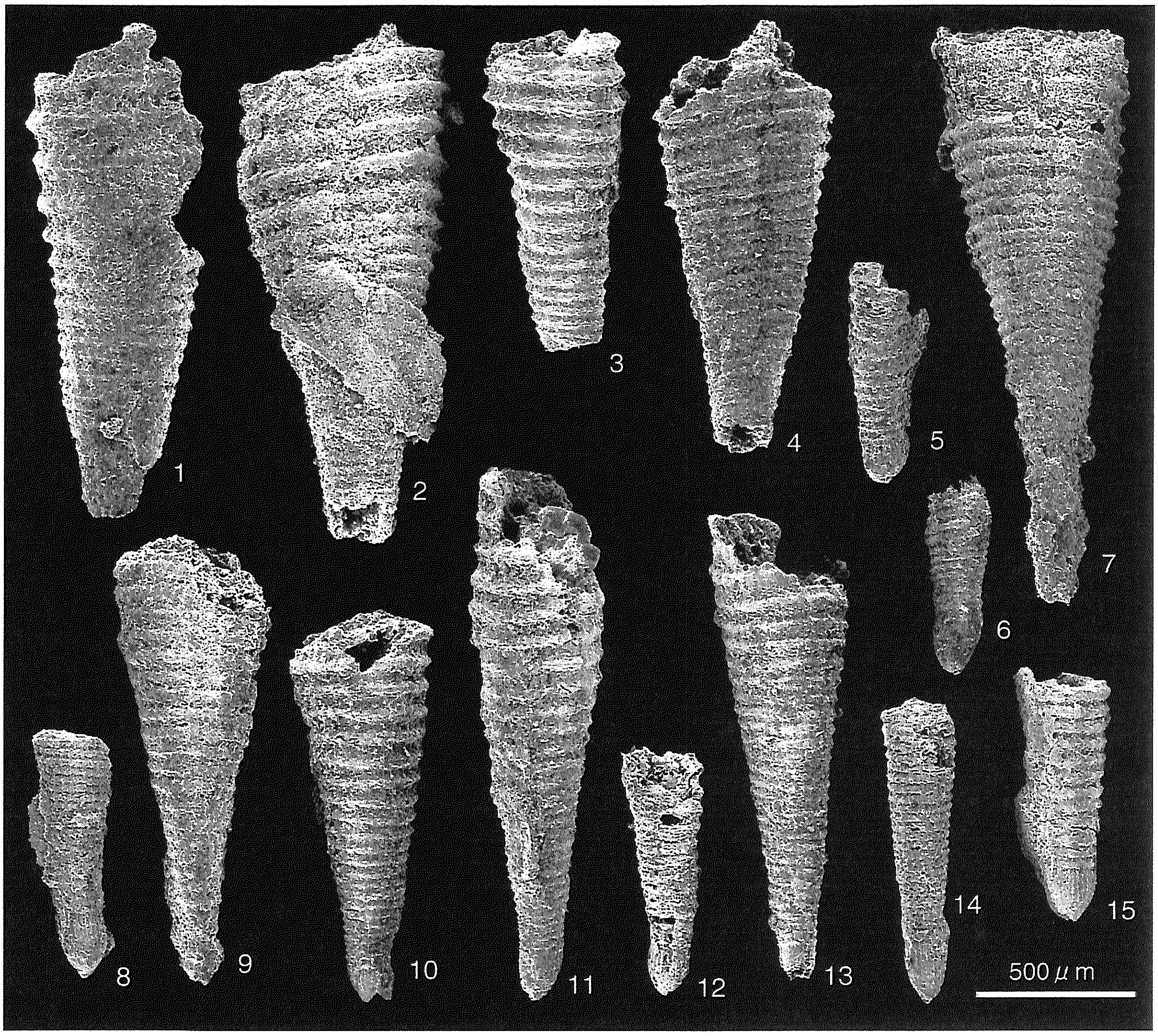
12, IGUT-ag0064, sample T.

13, IGUT-ag0065, sample T.

14, IGUT-ag0054, sample T.

15, IGUT-ag0057, sample T.

Plate 33



Explanation of Plate 34

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1, 2--*Scolopodus transtans* Druce and Jones, 1971.
1, posterior and aboral views, IGUT-ag1933, sample TAR -3.
2, posterior and aboral views, IGUT-ag1934, sample TAR -3.

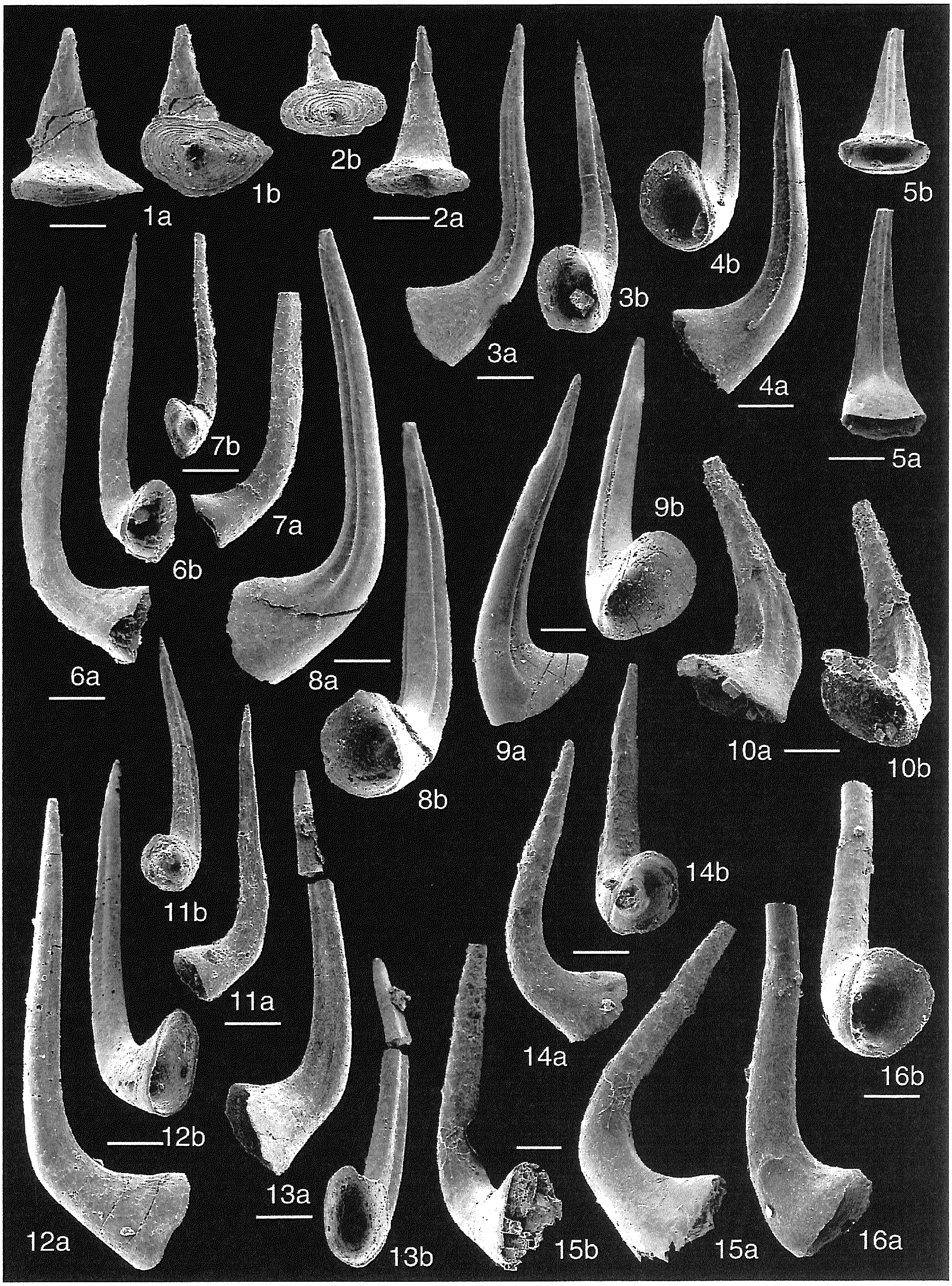
Figures 3-5, 8-10--*Variabiloconus bassleri* (Furnish, 1938).
3, lateral and aboral views of *c* element, IGUT-ag1935, sample TAR-8
4, lateral and aboral views of *b* element, IGUT-ag1936, sample TAR-4
5, posterior and aboral views of *c* element, IGUT-ag1937, sample TAR-27
8, lateral and aboral views of *c* element, IGUT-ag1938, sample TAR-7
9, lateral and aboral views of *b* element, IGUT-ag1939, sample TAR-7
10, lateral and aboral views of *a* element, IGUT-ag1940, sample TAR-8

Figures 6, 7--*Monocostatus sevierensis* (Miller, 1969).
6, lateral and aboral views of *c* element, IGUT-ag1941, sample TAR-6
7, lateral and aboral views of *c* element, IGUT-ag1942, sample TAR-9.

Figures 11-13--*Acodus sevierensis* Miller, 1969.
11, lateral and aboral views of *c* element, IGUT-ag1943, sample TAR-8.
12, lateral and aboral views of *b* element, IGUT-ag1944, sample TAR-6.
13, lateral and aboral views of *c* element, IGUT-ag1945, sample TAR-6.

Figures 14-16--*Teridontus nakamurai* (Nogami,l 1967).
14, lateral and aboral views, IGUT-ag1946, sample TAR-6.
15, lateral and aboral views, IGUT-ag1947, sample TAR-11.
16, lateral and aboral views, IGUT-ag1948, sample TAR-4.

Plate 34



1a
1b
2b
2a
3a
3b
4b
4a
5b
5a
6a
6b
7b
7a
8a
8b
9a
9b
10a
10b
11b
11a
12b
12a
13a
13b
14b
14a
15b
15a
16b
16a

Explanation of Plate 35

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-5--*Drepanoistodus concavus* (Branson and Mehl, 1933).
1, lateral and aboral views of *a* element, IGUT-ag1949, sample TAR -3.
2, lateral and aboral views of *a* element, IGUT-ag1950, sample TAR -7.
3, lateral and aboral views of *a* element, IGUT-ag1951, sample TAR -6.
4, lateral and aboral views of *c* element, IGUT-ag1952, sample TAR -7.
5, lateral and aboral views of *e* element, IGUT-ag1953, sample TAR -3.

Figures 6-11--*Drepanodus arcuatus* Pander, 1856.
6, lateral and aboral views of *q* element, IGUT-ag2164, sample TAR-27.
7, lateral and aboral views of *q* element, IGUT-ag2165, sample TAR-36.
8, lateral and aboral views of *q* element, IGUT-ag2166, sample TAR-13.
9, lateral and aboral views of *q* element, IGUT-ag2167, sample TAR-13.
10, lateral and aboral views of *q* element, IGUT-ag2168, sample TAR-36.
11, lateral and aboral views of *q* element, IGUT-ag1422, sample ST-4.

Figures 12, 14, 15-- *Coaptoconus quadraplicatus* (Branson and Mehl, 1933).
12, lateral and aboral views of *a* element, IGUT-ag1954, sample TAR-28.
14, lateral and aboral views of *c*element, IGUT-ag1955, sample TAR-4.
15, lateral and aboral views of *a* element, IGUT-ag1956, sample TAR-41.

Figures 13, 16, 17-- *Cornuodus longibasis* Serpagli, 1974.
13, lateral and aboral views of *c* element, IGUT-ag2169, sample TAR-38.
16, lateral and aboral views of *d* element, IGUT-ag2170, sample TAR-41.
17, lateral and aboral views of *d* element, IGUT-ag1417, sample ST-4.

Plate 35

1b
1a
2b
2a
3b
3a
4a
4b
5a
5b
6a
6b
7a
7b
8a
8b
9a
9b
10a
10b
11b
11a
12b
12a
13b
13a
14a
14b
15a
15b
16b
16a
17b
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Explanation of Plate 36

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-6, 8--*Coraptoconus bolites* (Repetski, 1982).

1, lateral and aboral views of *a* element, IGUT-ag1957, sample TAR -27.
2, lateral and aboral views of *a* element, IGUT-ag1958, sample TAR -36.
3, posterior and aboral views of *a* element, IGUT-ag1959, sample TAR -16.
4, lateral and aboral views of *ed* element, IGUT-ag1960, sample TAR -27.
5, lateral and aboral views of *c* element, IGUT-ag1961, sample TAR -28.
6, lateral and aboral views of *c* element, IGUT-ag1962, sample TAR -36.
8, lateral and aboral views of *e* element, IGUT-ag1963, sample TAR -32.

Figures 7, 9-12-- *Coraptoconus floweri* (Repetski, 1982).

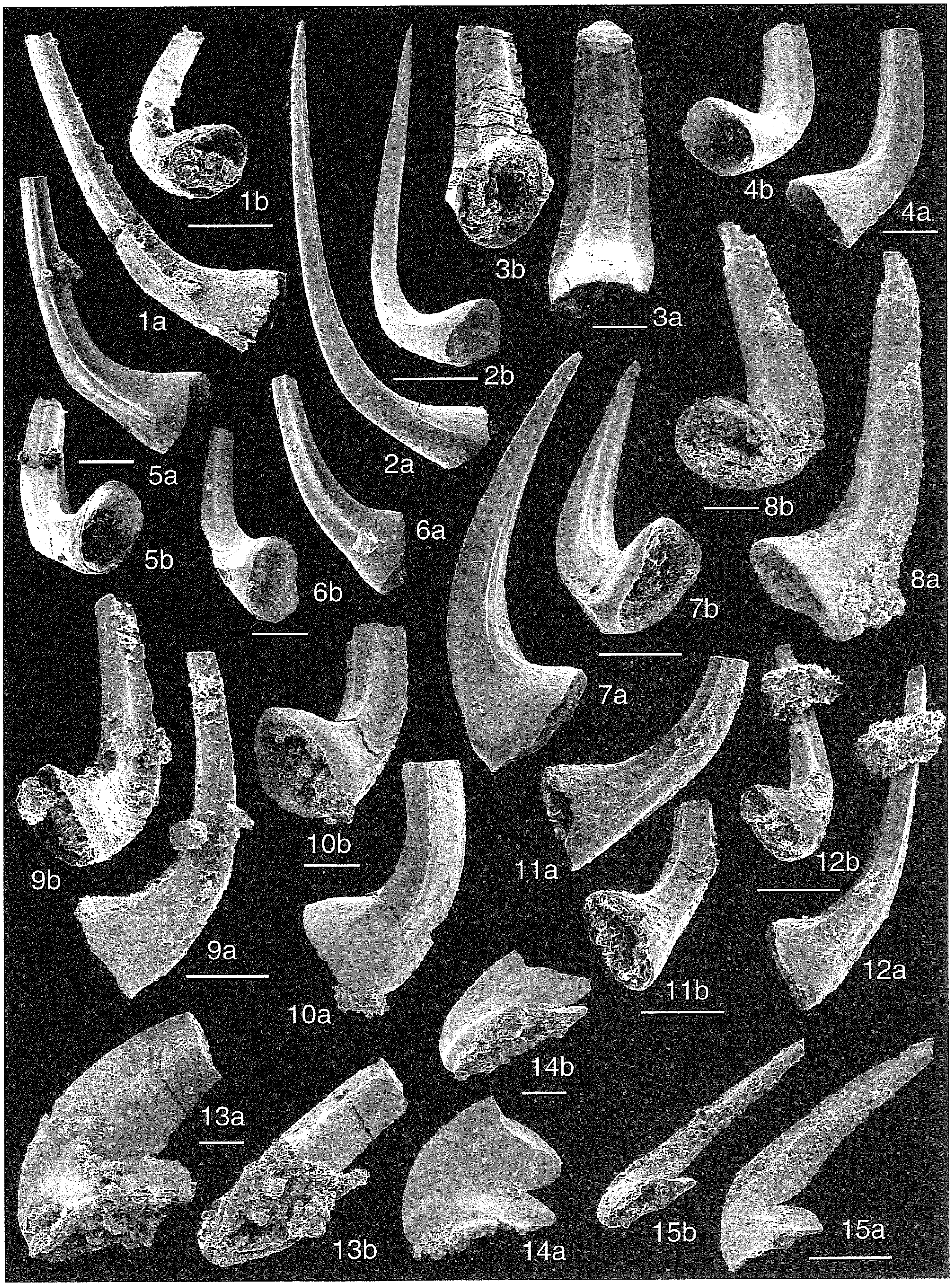
7, lateral and aboral views of *b* element, IGUT-ag1964, sample TAR-46.
9, lateral and aboral views of *b* element, IGUT-ag1965, sample TAR-44.
10, lateral and aboral views of *a* element, IGUT-ag1966, sample TAR-18.
11, lateral and aboral views of *a* element, IGUT-ag1967, sample TAR-22.
12, lateral and aboral views of *a* element, IGUT-ag1968, sample TAR-46.

Figure 13, 14--Gen. et sp. Indet. 18.

13, lateral and aboral views, IGUT-ag1969, sample TAR-46.
14, lateral and aboral views, IGUT-ag1970, sample TAR-46.

Figures 15-- Gen. et sp. Indet. 17.

15, lateral and aboral views, IGUT-ag1971, sample TAR-46.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Explanation of Plate 37

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figure 1--*Parapanderodus striatus* (Gravus and Ellison, 1941).
1, lateral and aboral views of *a* element, IGUT-ag1972, sample TAR -30.

Figures 2, 3, 6--Gen. et sp. Indet. 4.
2, lateral and aboral views, IGUT-ag1973, sample TAR-27.
3, posterior and aboral views, IGUT-ag1974, sample TAR-27.
6, posterior and aboral views, IGUT-ag1975, sample TAR-27.

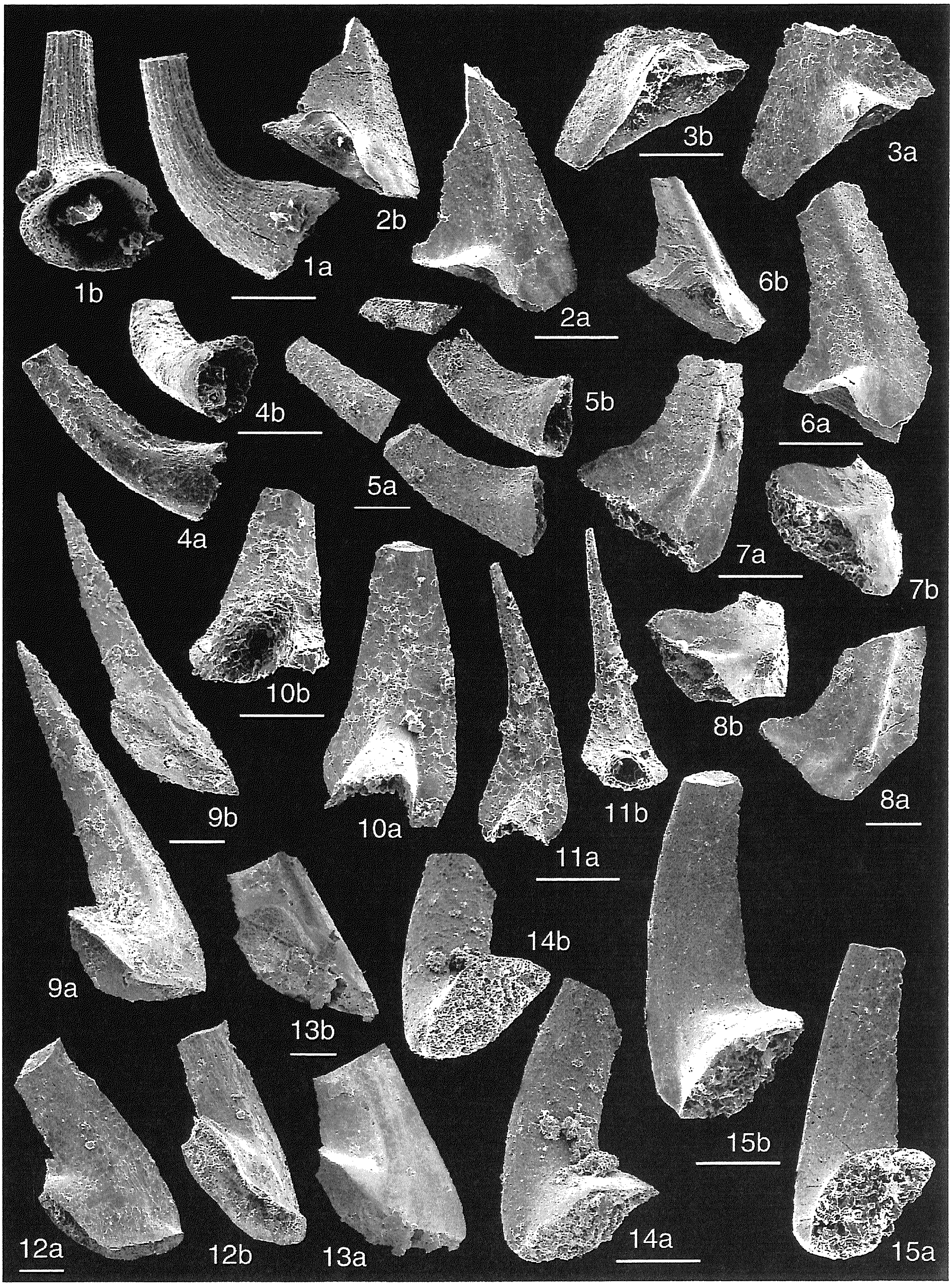
Figures 4, 5--Gen. et sp. Indet. 11.
4, lateral and aboral views, IGUT-ag1976, sample TAR-26
5, lateral and aboral views, IGUT-ag1977, sample TAR-23.

Figures 7, 8, 10, 11--*Rossodus manitouensis* Repetski and Ethington, 1983.
7, lateral and aboral views of *b* element, IGUT-ag1978, sample TAR-16.
8, lateral and aboral views of *b* element, IGUT-ag1979, sample TAR-20.
10, lateral and aboral views of *a* element, IGUT-ag1980, sample TAR-20.
11, lateral and aboral views of *a* element, IGUT-ag1981, sample TAR-21.

Figure 9--*Drepanoitodus suberectus* (Branson and Mehl, 1933).
9, lateral and aboral views, sample TAR -32.

Figures 12, 13--Gen. et sp. Indet. 9.
12, lateral and aboral views, IGUT-ag1982, sample TAR-32.
13 lateral and aboral views, IGUT-ag1983, sample TAR-32.

Figures 14, 15--*Scandodus* sp. cf. *S. furnishi* Lindström, 1955.
14, lateral and aboral views, IGUT-ag1984, sample TAR-36.
51, lateral and aboral views, IGUT-ag1985, sample TAR-36.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Explanation of Plate 38

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1, 2--*Filodontus* sp. cf. *F. filosus* (Ethington and Clark, 1964).
1, lateral and aboral views, IGUT-ag1986, sample TAR-46.
2, lateral and aboral views, IGUT-ag1987, sample TAR-46.

Figures 3-5, 9--Gen. et sp. Indet. 7.
3, lateral and aboral views, IGUT-ag1988, sample TAR-39.
4, lateral and aboral views, IGUT-ag1989, sample TAR-40.
5, lateral and aboral views, IGUT-ag1990, sample TAR-40.
9, lateral and aboral views, IGUT-ag1991, sample TAR-42.

Figures 6-8--Gen. et sp. Indet. 3.
6, lateral and aboral views, IGUT-ag1992, sample TAR-41.
7, lateral and aboral views, IGUT-ag1993, sample TAR-42.
8, lateral and aboral views, IGUT-ag1994, sample TAR-41.

Figures 10, 11--*Acodus comptus* (Branson and Mehl, 1933).
10, posterior and aboral views, IGUT-ag1995, sample TAR-42.
11, lateral and aboral views, IGUT-ag1996, sample TAR-42.

Figure 12--*Paroistodus* sp. A.
12, lateral and aboral views, IGUT-ag1997, sample TAR-46.

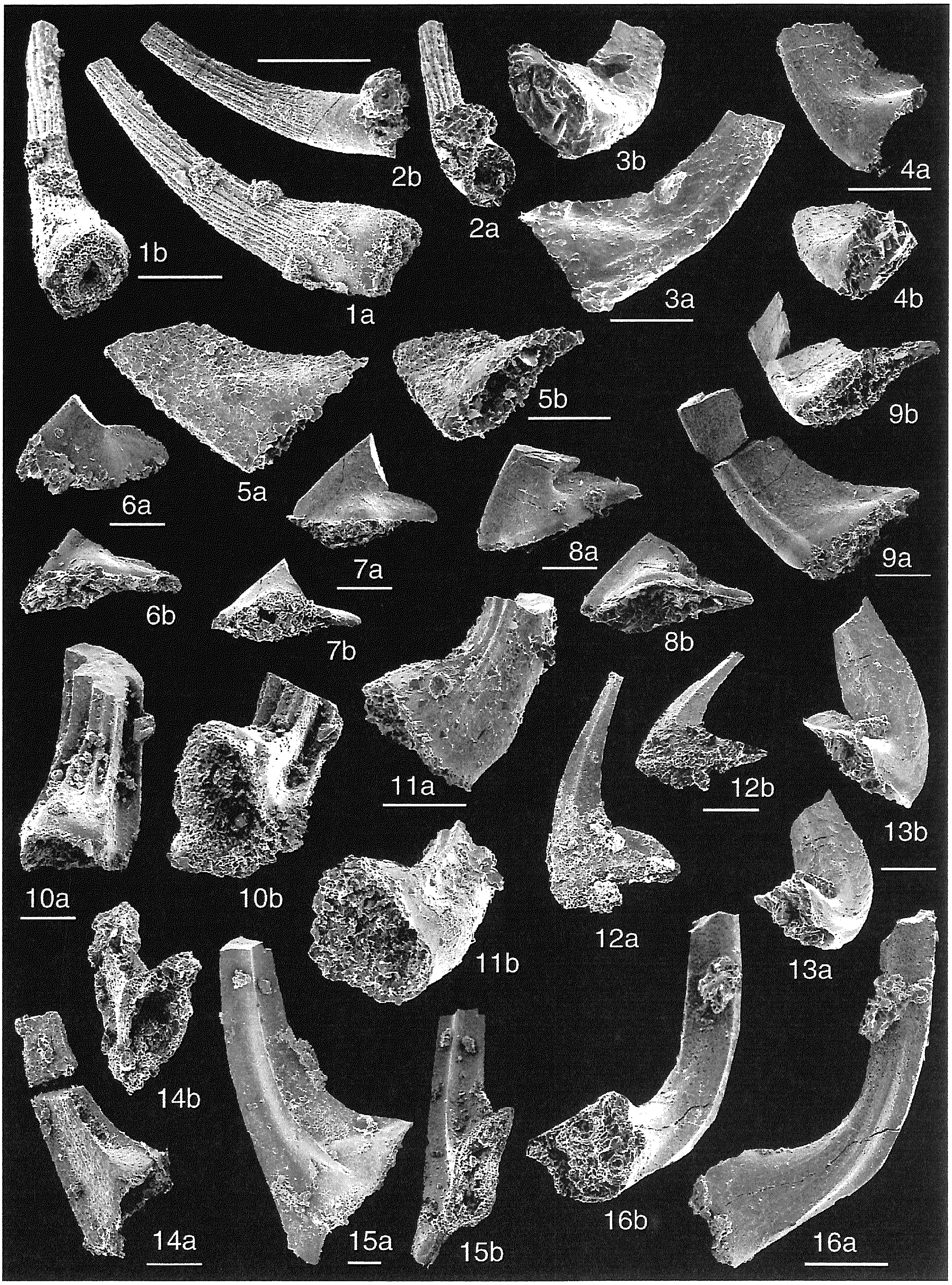
Figure 13--Gen. et sp. Indet. 19.
13, lateral and aboral views, IGUT-ag1998, sample TAR-18.

Figure 14--Gen. et sp. Indet. 1.
14, lateral and aboral views, IGUT-ag1999, sample TAR-23.

Figure 15--Gen. et sp. Indet. 2.
15 lateral and aboral views, IGUT-ag2000, sample TAR-46

Figure 16--*Acanthodus lineatus* (Furnish, 1938).
16, lateral and aboral views of *a* element, IGUT-ag2001, sample TAR-17.

Plate 38



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Explanation of Plate 39

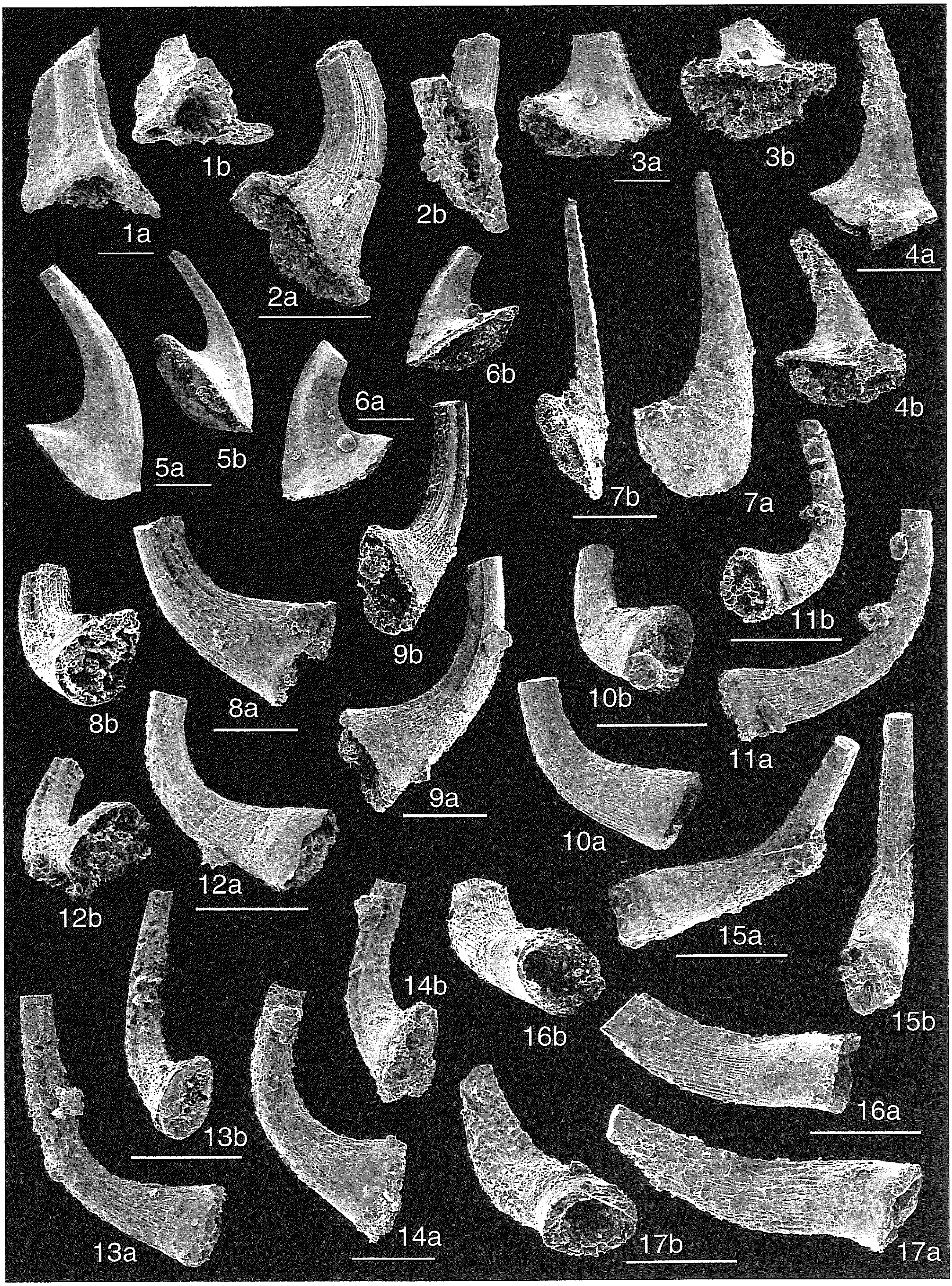
All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figure 1--*Juanognathus variabilis* Serpagli, 1974.
1, posterior and aboral views, IGUT-ag2002, sample TPP-21.

Figure 2--*Scolopodus* sp. C.
2, lateral and aboral views, IGUT-ag2003, sample TPP-15.

Figures 3-7--*Drepanoistodus forceps* (Lindström, 1955).
3, lateral and aboral views of *e* element, IGUT-ag2004, sample TAR-42.
4, lateral and aboral views of *c* element, IGUT-ag2005, sample TAR-46.
5, lateral and aboral views of *a* element, IGUT-ag2006, sample TAR-46.
6, lateral and aboral views of *a* element, IGUT-ag2007, sample TAR-45.
7, lateral and aboral views of *a* element, IGUT-ag2008, sample TAR-46.

Figures 7-17--*Scolopodus* sp. A.
7, lateral and aboral views of *d* element, IGUT-ag2009, sample TAR-46.
8, lateral and aboral views of *d* element, IGUT-ag2010, sample TAR-46.
10, lateral and aboral views of *c* element, IGUT-ag2011, sample TAR-46.
11, lateral and aboral views of *c* element, IGUT-ag2012, sample TAR-46.
12, lateral and aboral views of *d* element, IGUT-ag2013, sample TAR-46.
13, lateral and aboral views of *a/b* element, IGUT-ag2014, sample TAR-46.
14, lateral and aboral views of *a/b* element, IGUT-ag2015, sample TAR-46.
15, lateral and aboral views of *c* element, IGUT-ag2016, sample TAR-46.
16, lateral and aboral views of *e* element, IGUT-ag2017, sample TAR-46.
17, lateral and aboral views of *e* element, IGUT-ag2018, sample TAR-46.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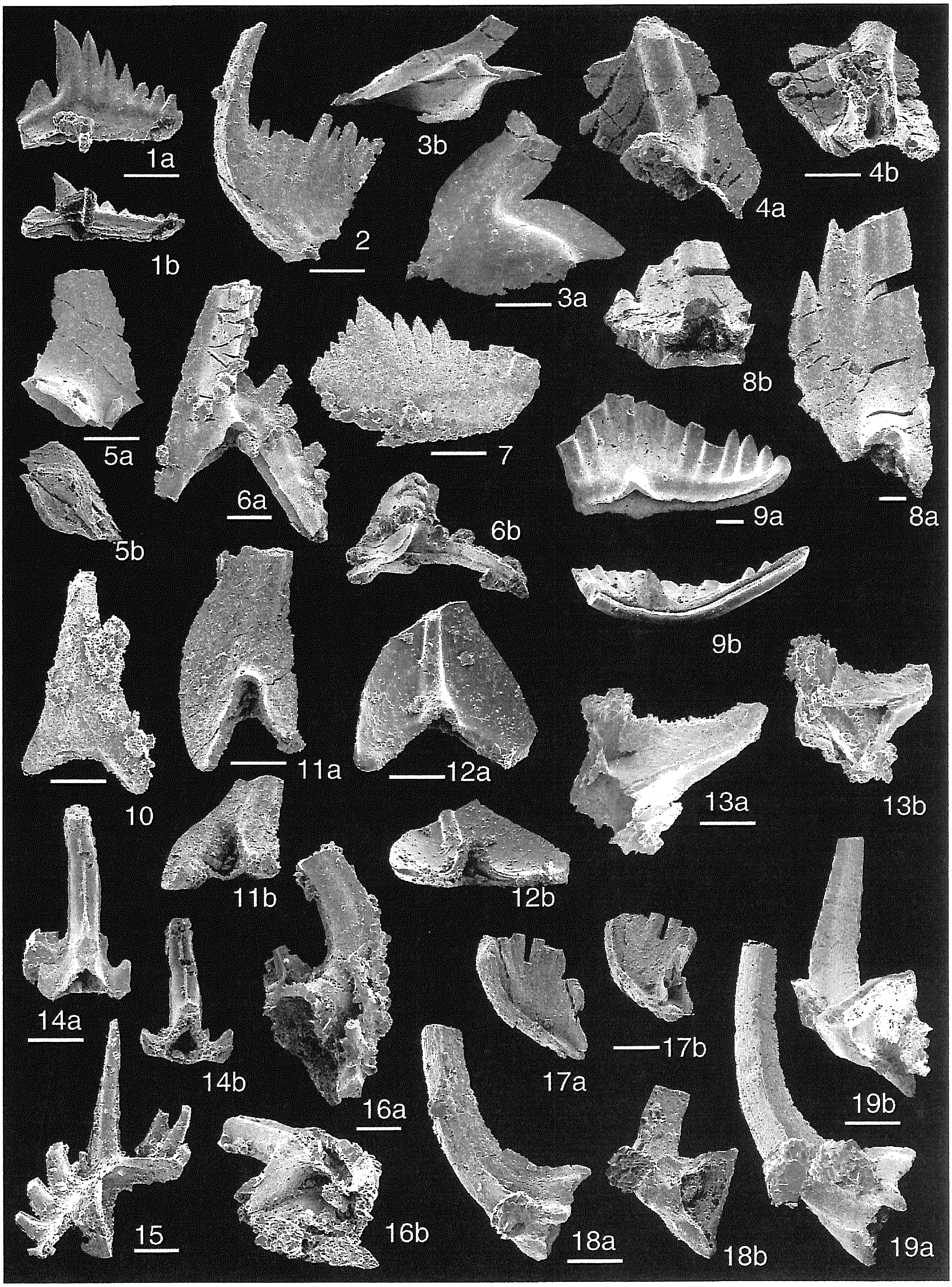
Explanation of Plate 40

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figure 1-- *Plectodina onychodonta* An and Xu, 1983.
    1, lateral and aboral views, IGUT-ag2019, sample TPP-18.
Figures 2, 3-- *Ansella* sp. C.
    2, lateral view of *a* element, IGUT-ag2020, sample TPP-18.
    3, lateral and aboral views of *e* element, IGUT-ag2021, sample TPP-18.
Figure 4--Gen. et sp. Indet. 14.
    4, posterior and aboral views, IGUT-ag2022, sample TPP-18.
Figure 5--Gen. et sp. Indet. 16.
    5, lateral and aboral views, IGUT-ag2023, sample TPP-17.
Figure 6--Gen. et sp. Indet. 8.
    6, lateral and aboral views, IGUT-ag2024, sample TPP-18.
Figure 7-- *Histiodella holodentata* Ethington and Clark, 1982.
    7, lateral view, IGUT-ag2025, sample TPP-15.
Figure 8,-- *Bergstroemognathus* sp. B
    8, posterior and aboral views, IGUT-ag2026, sample TPP-15.
Figure 9-- *Bergstroemognathus* sp. A
    9, posterior and aboral views, IGUT-ag2027, sample LAN-23.
Figure 10--*Aurilobodus* sp. cf. *A. leptosomatus* An et al., 1983
    10, posterior and aboral views of *t* element, IGUT-ag2028, sample TPP-13.
Figures 11, 12--*Aurilobodus leptosomatus* An et al., 1983
    11, posterior and aboral views of *t* element, IGUT-ag2029, sample TPP-15.
    12, posterior and aboral views of *s'* element, IGUT-ag2030, sample LAN-77.
Figure 13-- *Ansella* sp. D.
    13, lateral view of *b/c* element, IGUT-ag2031, sample TPP-27.
Figure 14-- *Erraticodon* sp. B.
    14, posterior and aboral views of *c* element, IGUT-ag2032, sample TPP-27.
Figure 15-- *Erraticodon patu* Cooper, 1981.
    15, posterior view of *f* element, IGUT-ag1816, sample TUW-15.
Figure 16-- *Erraticodon* sp. A.
    16, lateral and aboral views of *b* element, IGUT-ag1797, sample TUS-8.
Figure 17-- *Periodon* sp. B.
    17, lateral and aboral views of *b* element, IGUT-ag2033, sample TPP-17.
Figures 18, 19-- *Triangulodus brevibasis* (Serveeba, 1963).
    18, lateral and aboral views, IGUT-ag2034, sample TPP-28.
    19, lateral and aboral views, IGUT-ag2035, sample TPP-24.

Plate 40



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Explanation of Plate 41

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-4--*Protopanderodus gradatus* Serpagli, 1974.

1, lateral and aboral views of *a/b* element, IGUT-ag1811, sample TUW-13.

2, lateral and aboral views of *c* element, IGUT-ag1803, sample TUW-10.

3, lateral and aboral views of *e* element, IGUT-ag1808, sample TUW-12.

4, lateral and aboral views of *a/b* element, IGUT-ag1823, sample TUW-15.

Figures 5, 6--*Protopanderodus leonardii* Serpagli, 1974.

5, lateral and aboral views of *a/b* element, IGUT-ag1826, sample TUW-15.

6, lateral and aboral views of *f* element, IGUT-ag1838, sample TUW-15.

Figures 7, 8--*Walliserodus costatus* Dzik, 1976.

7, lateral and aboral views of *e* element, IGUT-ag1800, sample TUW-2.

8, lateral and aboral views of *a/b* element, IGUT-ag1799, sample TUW-2.

Figures 9-12--*Periodon aculeatus* Hadding, 1913.

9, lateral and aboral views of *a* element, IGUT-ag1807, sample TUW-10.

10, lateral and aboral views of *b* element, IGUT-ag1837, sample TUW-15.

11, lateral and aboral views of b element, IGUT-ag1839, sample TUW-16.

12, lateral and aboral views of *e* element, IGUT-ag1809, sample TUW-13.

Figures 13-16--*Paroistodus originalis* (Sergeeva, 1963).

13, lateral and aboral views of *r* element, IGUT-ag1834, sample TUW-15.

14, lateral and aboral views of *q* element, IGUT-ag1814, sample TUW-15.

15, lateral and aboral views of *q* element, IGUT-ag1831, sample TUW-15.

16, lateral and aboral views of *q* element, IGUT-ag1822, sample TUW-15.

Figure 17--*Oistodus* sp. A.

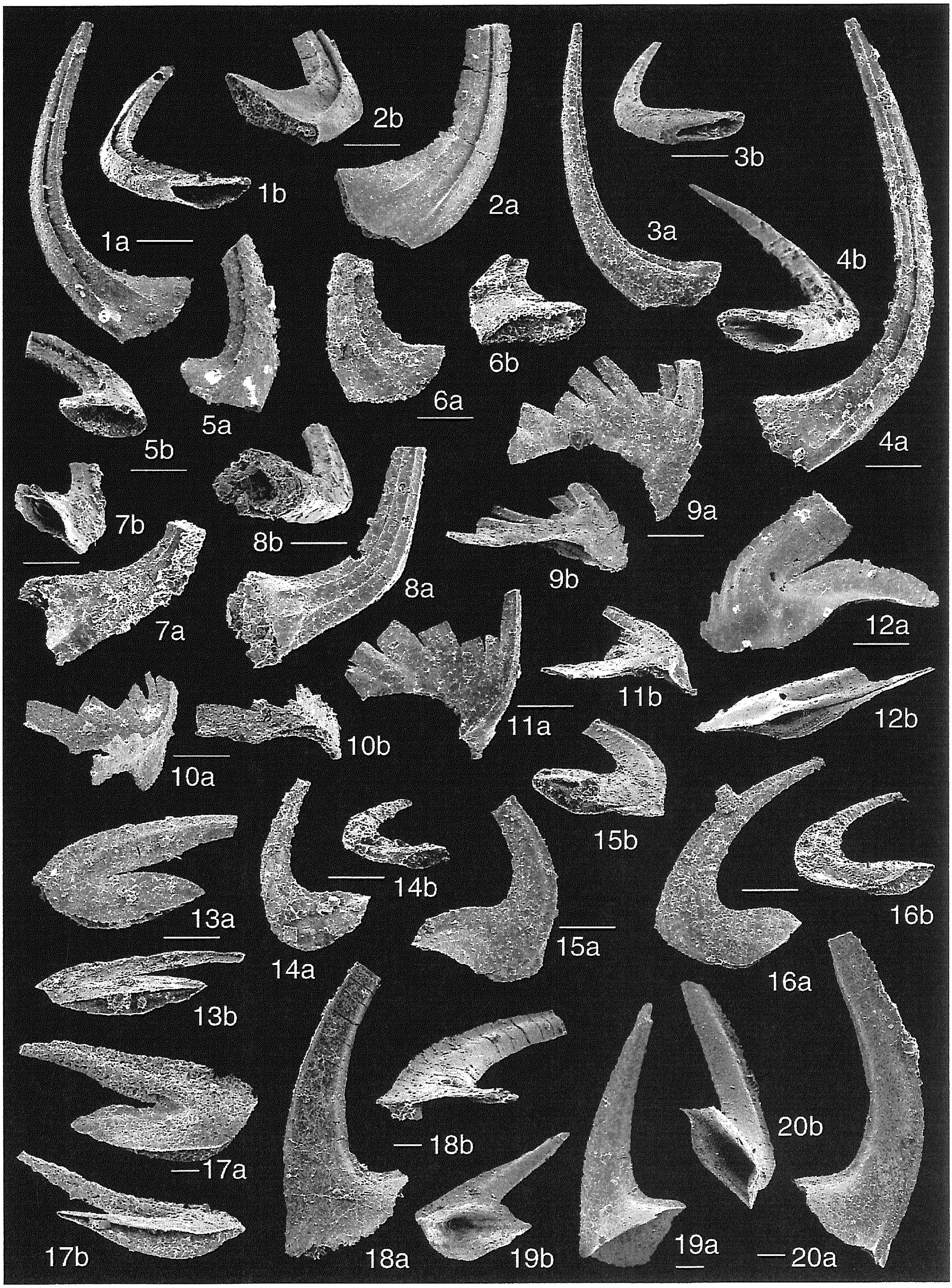
17, lateral and aboral views of *r* element, IGUT-ag1806, sample TUW-10.

Figures 18-20-- *Triangulodus larapintinensis* (Crespin, 1943).

18, lateral and aboral views of *e* element, IGUT-ag1810, sample TUW-3.

19, lateral and aboral views of *f* element, IGUT-ag1813, sample TUW-14.

20, lateral and aboral views of *a* element, IGUT-ag1812, sample TUW-14.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Explanation of Plate 42

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

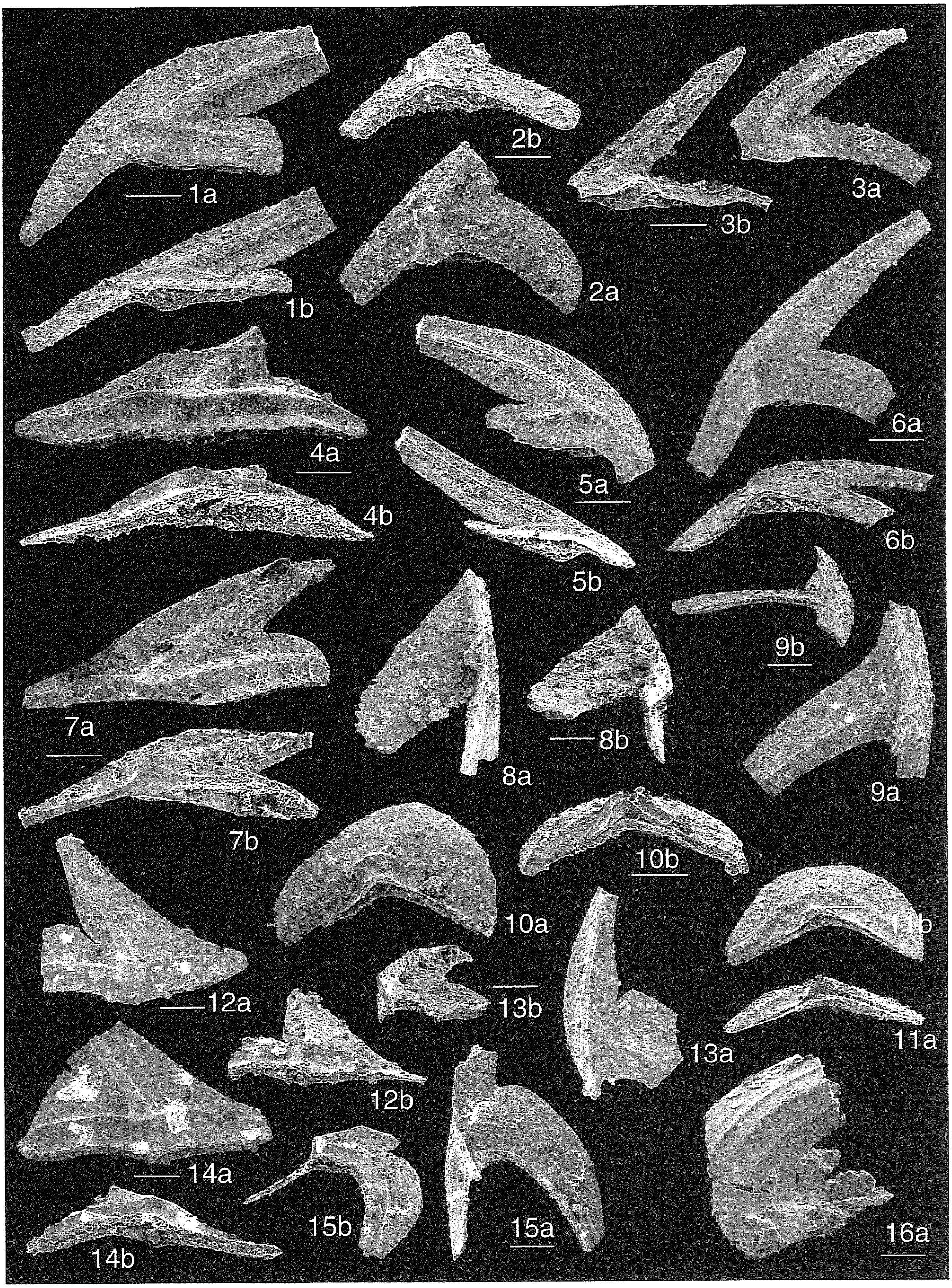
Figures 1-3, 5, 6-- *Protoprioniodus yapu* Cooper, 1981.
1, posterior and aboral views of *g* element, IGUT-ag1832, sample TUW-15.
2, lateral and aboral views of *f* element, IGUT-ag1820, sample TUW-15.
3, posterior and aboral views of *b* element, IGUT-ag1824, sample TUW-15.
5, posterior and aboral views of *g* element, IGUT-ag1821, sample TUW-15.
6, lateral and aboral views of *f* element, IGUT-ag1835, sample TUW-15.

Figures 4, 7-11 *Cooperignathus nyinti* (Cooper, 1981).
4, anterior and aboral views of *e* element, IGUT-ag1825, sample TUW-15.
7, anterior and aboral views of *e* element, IGUT-ag1818, sample TUW-15.
8, lateral and aboral views of *b* element, IGUT-ag1819, sample TUW-15.
9, lateral and aboral views of *b* element, IGUT-ag1836, sample TUW-15.
10, lateral and aboral views of *f* element, IGUT-ag1833, sample TUW-15.
11, lateral and aboral views of *f* element, IGUT-ag1830, sample TUW-15.

Figures 12-15--*Cooperignathus aranda* (Cooper, 1981).
12, anterior and aboral views of *e* element, IGUT-ag1827, sample TUW-15.
13, anterior and aboral views of *c* element, IGUT-ag1815, sample TUW-15.
14, lateral and aboral views of *e* element, IGUT-ag1829, sample TUW-15.
15, lateral and aboral views of *b* element, IGUT-ag1817, sample TUW-15.

Figure 16--*Scolopodus* sp. B.
12, lateral view, IGUT-ag 2036, sample TUS-11.

Plate 42



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Explanation of Plate 43

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-4-- *Acodus* sp. A..

1, lateral and aboral views of *b* element, IGUT-ag1805, sample TUW-10.

2, lateral and aboral views of *f* element, IGUT-ag1804, sample TUW-10.

3, lateral and aboral views of *e* element, IGUT-ag1801, sample TUW-10.

4, posterior and aboral views of *c* element, IGUT-ag1802, sample TUW-10.

Figures 5, 6--*Oepikodus* sp. A.

5, lateral view of *b* element, IGUT-ag 2037, sample LAN-70.

6, lateral and aboral views of *e* element, IGUT-ag 2038, sample LAN-70.

Figures 7-9--*Acodus* sp. cf. *A. deltatus* (Lindström, 1955)

7, posterior and aboral views of *c* element, IGUT-ag 2039, sample LAN-76.

8, lateral and aboral views of *b* element, IGUT-ag 2040, sample LAN-76.

9, lateral and aboral views of *a* element, IGUT-ag 2041, sample LAN-76.

Figures 10-13--*Drepanoistodus costatus* (Abaimove, 1971)

10, lateral and aboral views of *p* element, IGUT-ag 2042, sample LAN-9.

11, lateral and aboral views of *q* element, IGUT-ag 2043, sample LAN-8.

12, lateral and aboral views of *q* element, IGUT-ag 2044, sample LAN-77.

13, lateral and aboral views of *q* element, IGUT-ag 2045, sample LAN-77.

Figures 14, 16-19--*Scolopodus quadratus* Pander, 1856

14, lateral and aboral views of *g* element, IGUT-ag 2046, sample LAN-77.

16, lateral and aboral views of *c* element, IGUT-ag 2047, sample LAN-8.

17, lateral and aboral views of *c* element, IGUT-ag 2048, sample LAN-77.

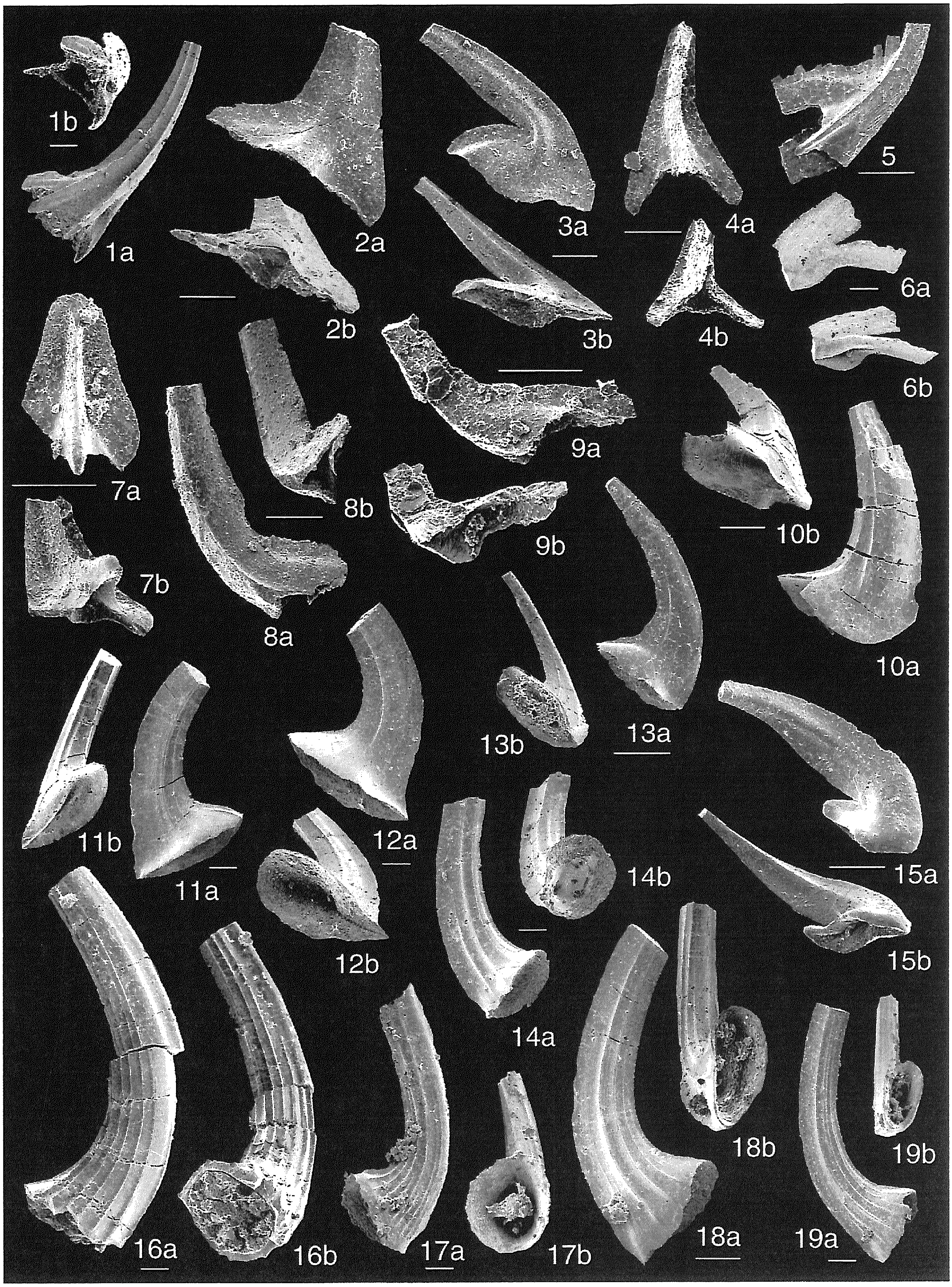
18, lateral and aboral views of *a* element, IGUT-ag 2049, sample LAN-77.

19, lateral and aboral views of *b* element, IGUT-ag 2050, sample LAN-77.

Figure 15--Gen. et sp. Indet. 21.

15, lateral and aboral views, IGUT-ag 2051, sample LAN-76.

Plate 43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Explanation of Plate 44

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-7--*Panderodus nogamii* (Lee, 1975)

1, lateral and aboral views of *c* element, IGUT-ag 2052, sample LAN-77.
2, lateral and aboral views of *b* element, IGUT-ag 2053, sample LAN-77.
3, lateral and aboral views of *b* element, IGUT-ag 2054, sample LAN-78.
4, lateral and aboral views of *a* element, IGUT-ag 2055, sample LAN-77.
5, lateral and aboral views of *g* element, IGUT-ag 2056, sample LAN-77.
6, lateral and aboral views of *f* element, IGUT-ag 2057, sample LAN-78.
7, lateral and aboral views of *f* element, IGUT-ag 2058, sample LAN-76.

Figures 8, 9--*Scolopouds multicostatus* Barnes and Tuke, 1970.

1, lateral and aboral views of *f/g* element, IGUT-ag 2059, sample LAN-77.
2, lateral and aboral views of *f/g* element, IGUT-ag 2060, sample LAN-77.

Figure 10--*Protopanderodus varicostatus* (Sweet and Bergström, 1962)

10, lateral and aboral views, IGUT-ag 2061, sample LAN-70.

Figure 11--*Prioniodus amadeus* Cooper, 1981.

11, lateral and aboral views of *c* element, IGUT-ag 2062, sample LAN-8.

Figures 12-14--*Periodon* sp. A

12, lateral and aboral views of *g* element, IGUT-ag 2063, sample LAN-77.
13, lateral and aboral views of *f* element, IGUT-ag 2064, sample LAN-77.
14, lateral and aboral views of *a* element, IGUT-ag 2065, sample LAN-77.

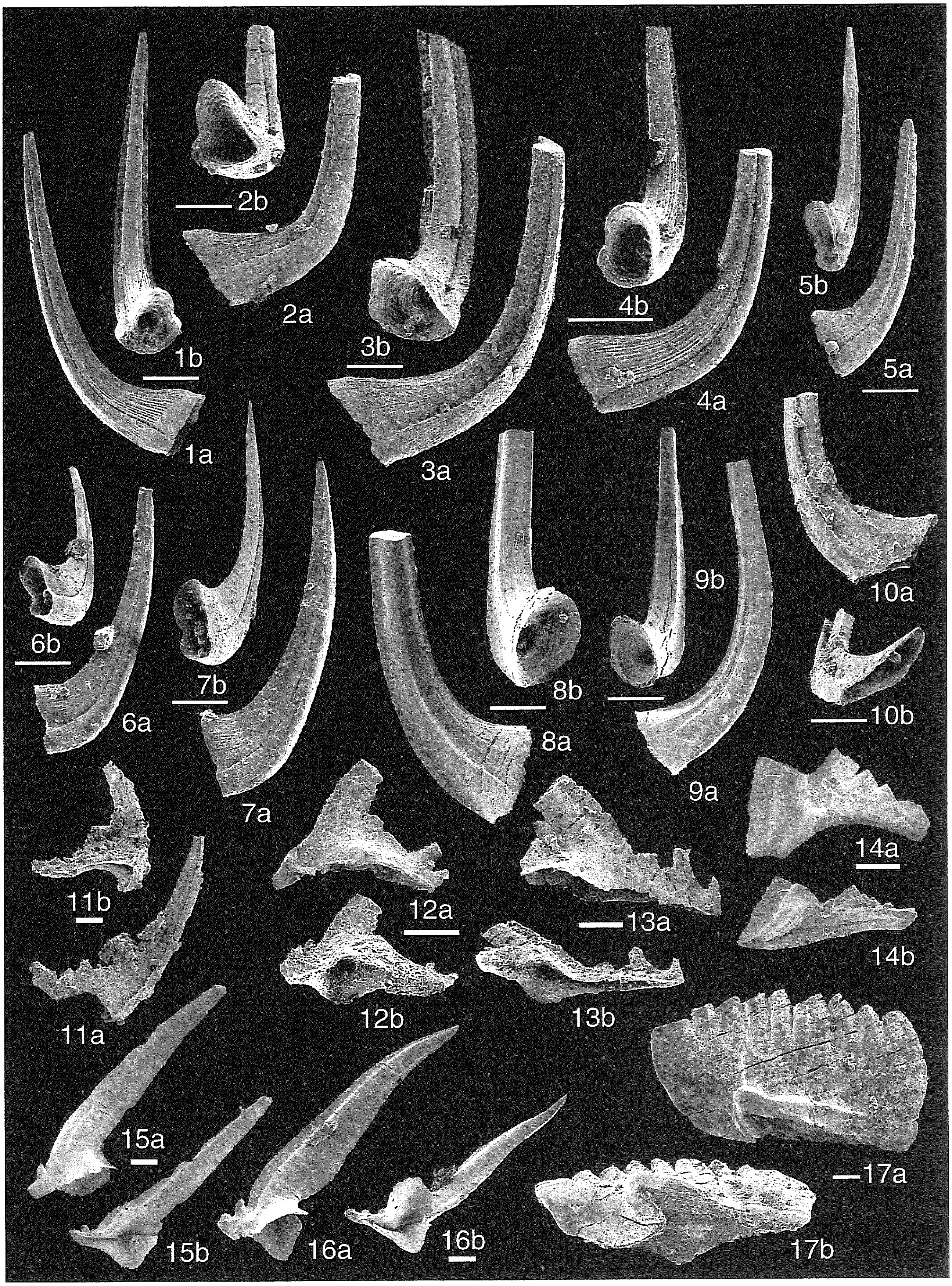
Figures 15, 16--Gen. et sp. Indet. 13.

15, lateral and aboral views, IGUT-ag2171, sample LAN-8.
16, lateral and aboral views, IGUT-ag2172, sample LAN-8.

Figure 17--*Jumodontus gananda* Cooper, 1981.

17, lateral and aboral views, IGUT-ag2173, sample LAN-77.

Plate 44



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Explanation of Plate 45

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-4--*Pygodus anserinus* Lamont and Lindström, 1957.
1, *f* element, IGUT-ag1069 sample ST-2.
2, *f* element, IGUT-ag1068, sample ST-2.
3, *f* element, IGUT-ag1005, sample ST-1.
4, lateral and oral views of *g* element, IGUT-ag1004, sample ST-1.

Figures 5, 10--*Panderodus* sp. A.
5, lateral and aboral views, IGUT-ag1441, sample ST-5.
10, lateral and aboral views, IGUT-ag1423, sample ST-4

Figures 6-9--*Panderodus gracilis* (Sweet and Bergström, 1933).
6, lateral and oral views, IGUT-ag1154, sample ST-3.
7, lateral and oral views, IGUT-ag1061, sample ST-2.
8, lateral and oral views, IGUT-ag1001, sample ST-1.
9, lateral and oral views, IGUT-ag1060, sample ST-2.

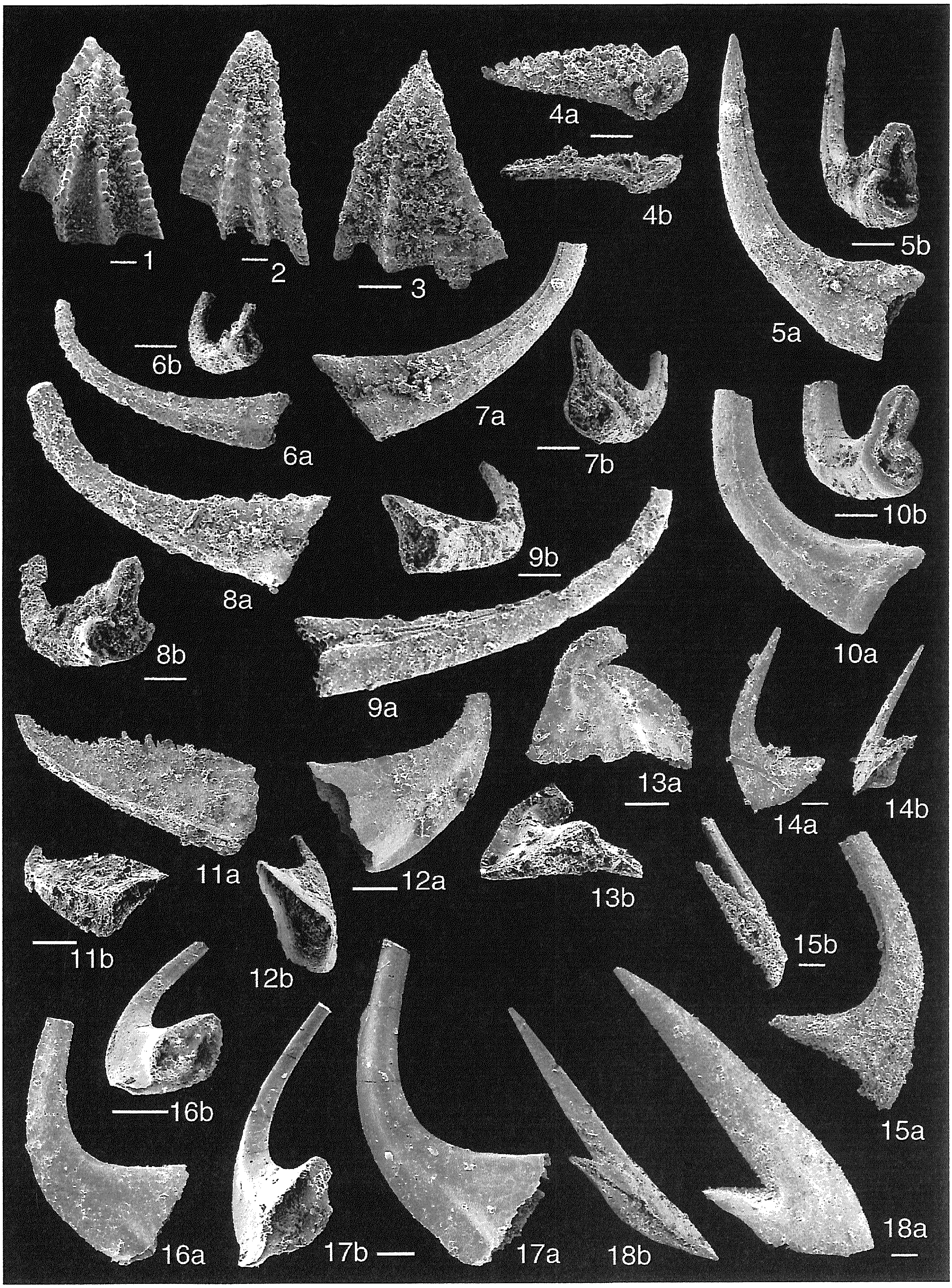
Figures 11-13--*Ansella jemtlandica* (Löfgren, 1978).
11, lateral and aboral views of *d* element, IGUT-ag2066, sample LAN-27.
12, lateral and aboral views of *f* element, IGUT-ag2067, sample LAN-27.
13, lateral and aboral views of *e* element, IGUT-ag2068, sample LAN-27.

Figure 14--Gen. et sp. Indet. 15.
14, lateral and aboral views, IGUT-ag 1437, sample ST-4.

Figure 15--*Besselodus semisymmetricus* (Hamari, 1966).
15, lateral and aboral views, IGUT-ag1153, sample ST-3.

Figures 16, 17--Gen. et sp. Indet. 12.
16 lateral and aboral views, IGUT-ag2069, sample LAN-31.
17 lateral and aboral views, IGUT-ag2070, sample LAN-33.

Figure 18--Gen. et sp. Indet. 6.
18, lateral and aboral views, IGUT-ag 1438, sample ST-4.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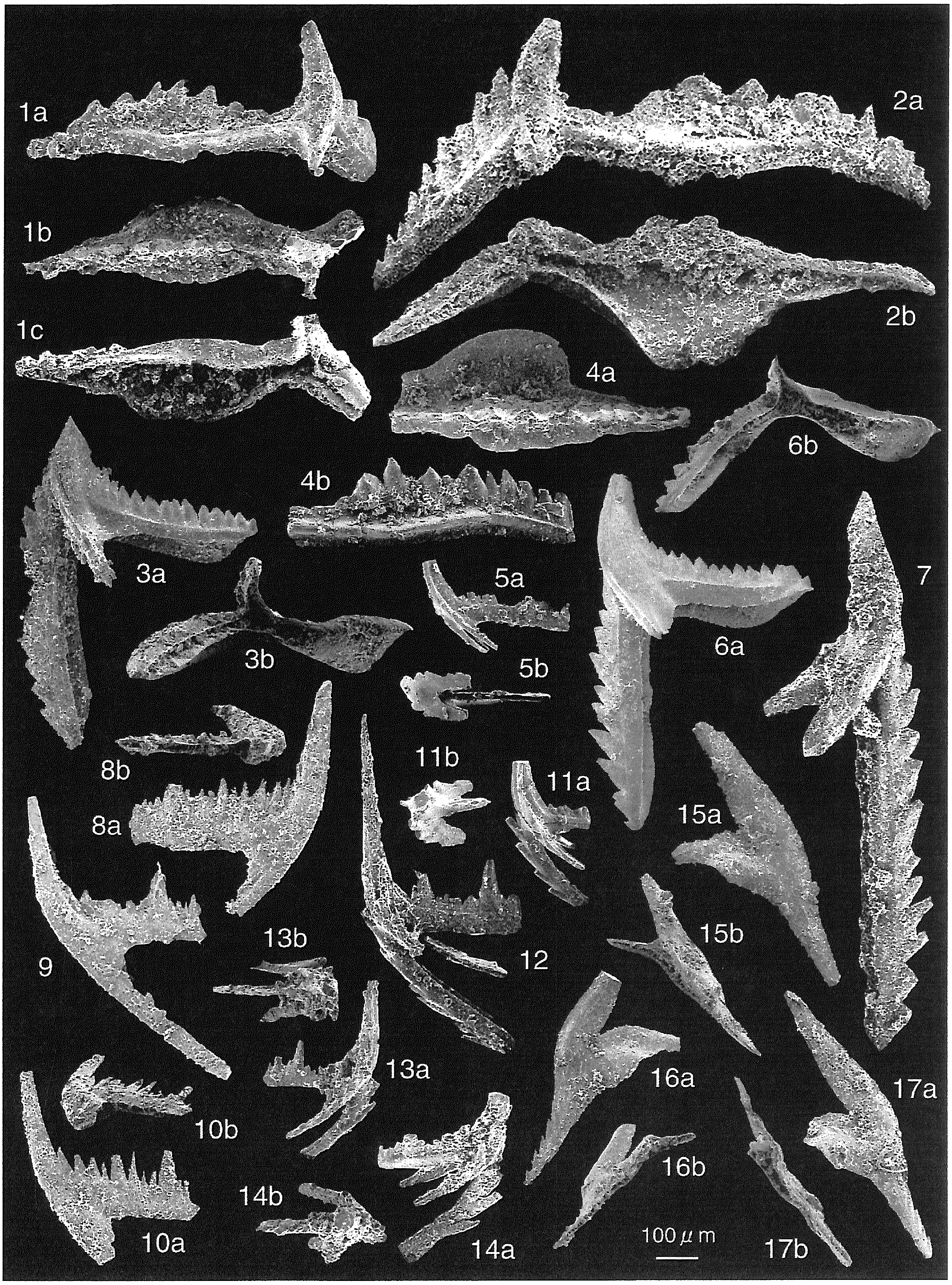
Explanation of Plate 46

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-17-- *Baltoniodus* sp. cf. *B. variabilis* (Bergström, 1962)

1, lateral, oral and aboral views of *f* element, IGUT-ag1262, sample ST-4.
2, lateral and aboral views of *f* element, IGUT-ag1018, sample ST-2.
3, lateral and aboral views of *g* element, IGUT-ag1243, sample ST-4.
4, lateral and oral views of *f* element, IGUT-ag1306, sample ST-4.
5, lateral and aboral views of *e* element, IGUT-ag1332, sample ST-4.
6, lateral and aboral views of *g* element, IGUT-ag1009, sample ST-2.
7, lateral view of *g* element, IGUT-ag1080, sample ST-3.
8, lateral and aboral views of *a* element, IGUT-ag1037, sample ST-2.
9, lateral view of *a* element, IGUT-ag1341, sample ST-4.
10, lateral and aboral views of *a* element, IGUT-ag1133, sample ST-3.
11, lateral and oral views of *d* element, IGUT-ag1365, sample ST-4.
12, lateral view of *d* element, IGUT-ag1372, sample ST-4.
13, lateral and oral views of *d* element, IGUT-ag1361, sample ST-4.
14, lateral and oral views of *d* element, IGUT-ag1362, sample ST-4.
15, lateral and aboral views of *e* element, IGUT-ag1163, sample ST-4.
16, lateral and aboral views of *e* element, IGUT-ag1168, sample ST-4.
17, lateral and aboral views of *e* element, IGUT-ag1172, sample ST-4.

Plate 46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Explanation of Plate 47

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1, 2--*Ansella* sp. B.

1, lateral and aboral views of *a* element, IGUT-ag1649, sample ST-10.

2, lateral and aboral views of *a* element, IGUT-ag1770, sample ST-18.

Figure 3--*Ansella* sp. A.

3, lateral and aboral views of *a* element, IGUT-ag1158, sample ST-4.

Figures 4, 8-10, 12-17--*Scabbardella altipes* (Henningsmoen, 1948).

4, lateral and aboral views of *s* element, IGUT-ag1748, sample ST-12.

8, lateral and aboral views of *s* element, IGUT-ag1544, sample ST-7.

9, lateral and aboral views of *s* element, IGUT-ag1500, sample ST-6.

10, lateral and aboral views of *t* element, IGUT-ag1723, sample ST-12.

12, lateral and aboral views of *t* element, IGUT-ag1475, sample ST-6.

13, lateral and aboral views of *t* element, IGUT-ag1763, sample ST-17.

14, lateral and aboral views of *t* element, IGUT-ag1682, sample ST-10.

15, lateral and aboral views of *t* element, IGUT-ag1495, sample ST-6.

16, lateral and aboral views of *t* element, IGUT-ag1703, sample ST-11.

17, lateral and aboral views of *t* element, IGUT-ag1737, sample ST-12.

Figures 5-7,11--*Dapsilodus mutatus* (Branson and Mehl, 1933).

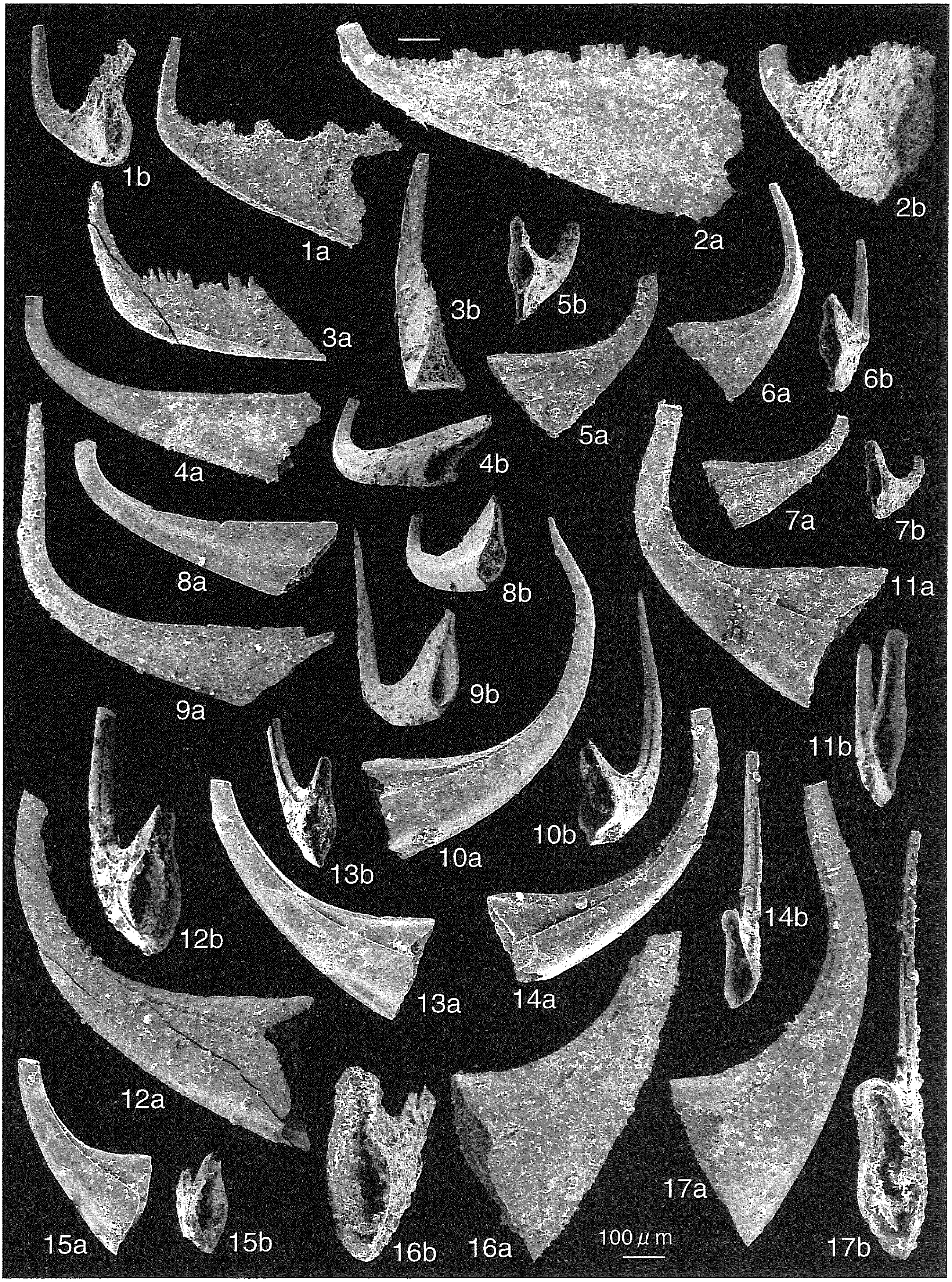
5, lateral and aboral views, IGUT-ag1651, sample ST-10.

6, lateral and aboral views, IGUT-ag1439, sample ST-5.

7, lateral and aboral views, IGUT-ag1420, sample ST-4.

11, lateral and aboral views, IGUT-ag1454, sample ST-6.

Plate 47



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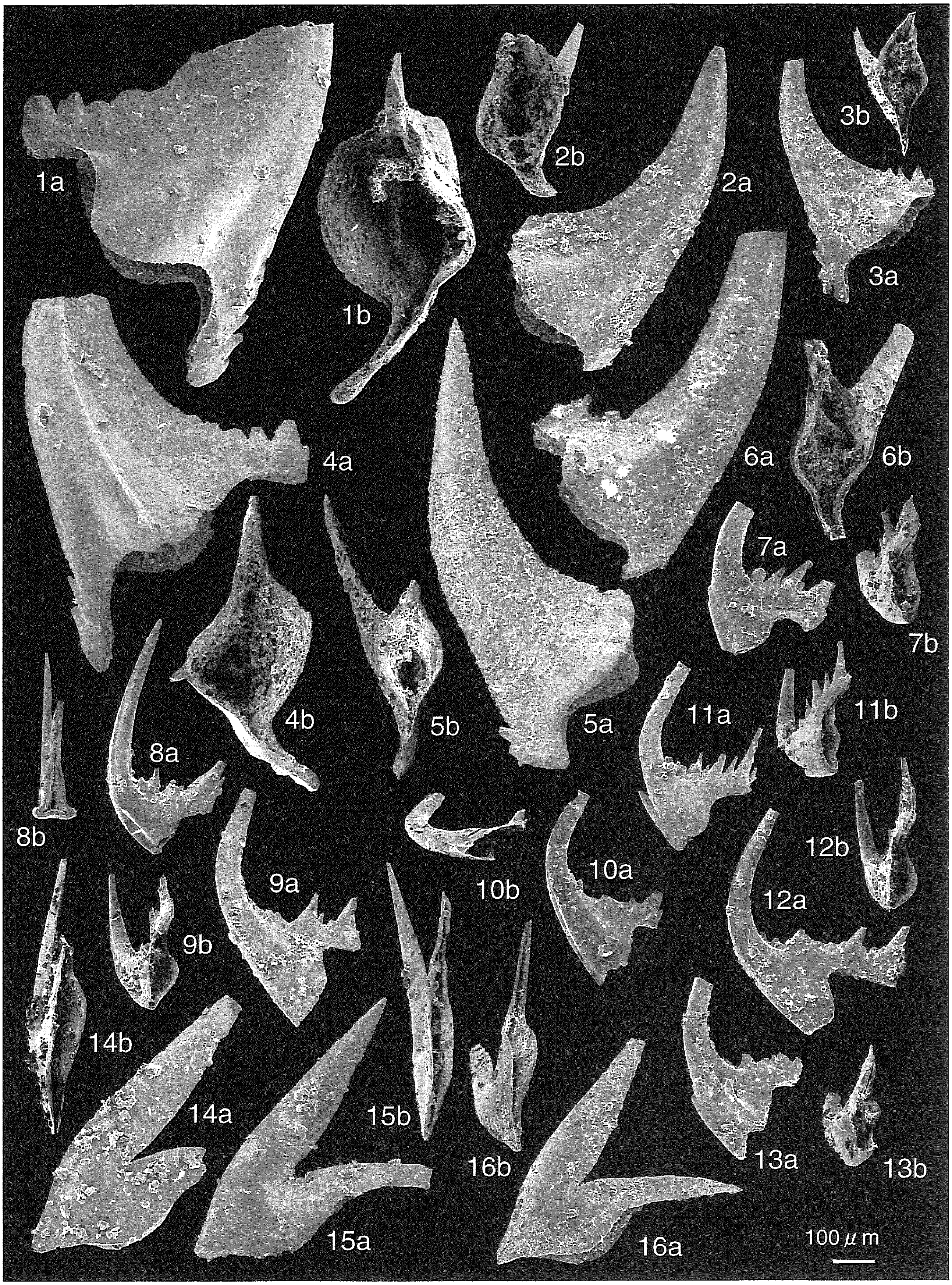
Explanation of Plate 48

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-16-- *Hamarodus europaeus* (Serpagli, 1974)

1, lateral and aboral views of *f* element, IGUT-ag1690, sample ST-11.
2, lateral and aboral views of *f* element, IGUT-ag1623, sample ST-9.
3, lateral and aboral views of *f* element, IGUT-ag1560, sample ST-8.
4, lateral and aboral views of *f* element, IGUT-ag1691, sample ST-11.
5, lateral and aboral views of *f* element, IGUT-ag1659, sample ST-10.
6, lateral and aboral views of *f* element, IGUT-ag1513, sample ST-7.
7, lateral and aboral views of *a* element, IGUT-ag1468, sample ST-6.
8, lateral and aboral views of *c* element, IGUT-ag1564, sample ST-8.
9, lateral and aboral views of *b* element, IGUT-ag1718, sample ST-12.
10, lateral and aboral views of *b* element, IGUT-ag1719, sample ST-12.
11, lateral and aboral views of *a* element, IGUT-ag1469, sample ST-6.
12, lateral and aboral views of *b* element, IGUT-ag1775, sample ST-18.
13, lateral and aboral views of *d* element, IGUT-ag1470, sample ST-6.
14, lateral and aboral views of *e* element, IGUT-ag1462, sample ST-6.
15, lateral and aboral views of *e* element, IGUT-ag1460, sample ST-6.
16, lateral and aboral views of *e* element, IGUT-ag1654, sample ST-10.

Plate 48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Explanation of Plate 49

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1, 2--Gen, et sp. Indet. 20.
1, lateral and aboral views, IGUT-ag2071, sample LAN-33.
2, lateral and aboral views, IGUT-ag2072, sample LAN-33.

Figures 3, 6--*Amorphognathodus* sp. A.
3, lateral and oral views of *f* element, IGUT-ag1447, sample ST-6.
6, lateral and aboral views of *g* element, IGUT-ag1446, sample ST-6.

Figure 4--*Scabbardella* sp. cf. *S. altipes* (Henningsmoen, 1948).
4, lateral and oral views, IGUT-ag1663, sample ST-6.

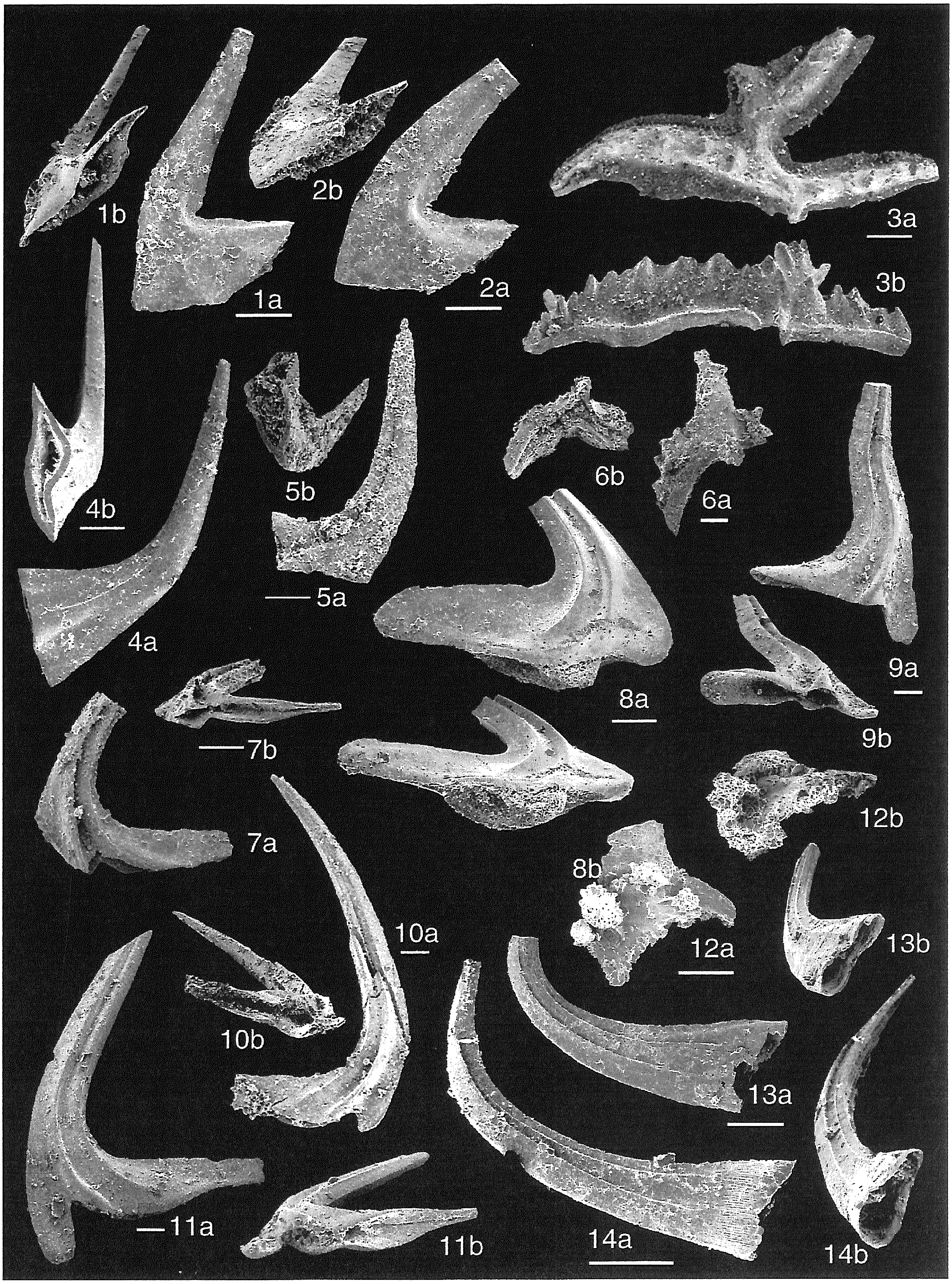
Figure 5--*Protopanderouds* sp. A.
5, lateral and oral views, IGUT-ag1442, sample ST-5.

Figures 7-11--*Protopanderouds liripipus* Kennedy, Barnes, and Uyeno, 1979.
7, lateral and aboral views, IGUT-ag1473, sample ST-7.
8, lateral and aboral views, IGUT-ag2073, sample LAN-35.
9, lateral and aboral views, IGUT-ag2074, sample LAN-37.
10, lateral and aboral views, IGUT-ag1518, sample ST-7.
11, lateral and aboral views, IGUT-ag1693, sample ST-11.

Figure 12--Gen, et sp. Indet. 10.
1, lateral and aboral views, IGUT-ag2174, sample TAR-42.

Figures 13, 14--*Panderodus sp. cf. serratus* Rexroad, 1967.
13, lateral and aboral views, IGUT-ag2175, sample LAN-49.
14, lateral and aboral views, IGUT-ag2176, sample LAN-49.

Plate 49



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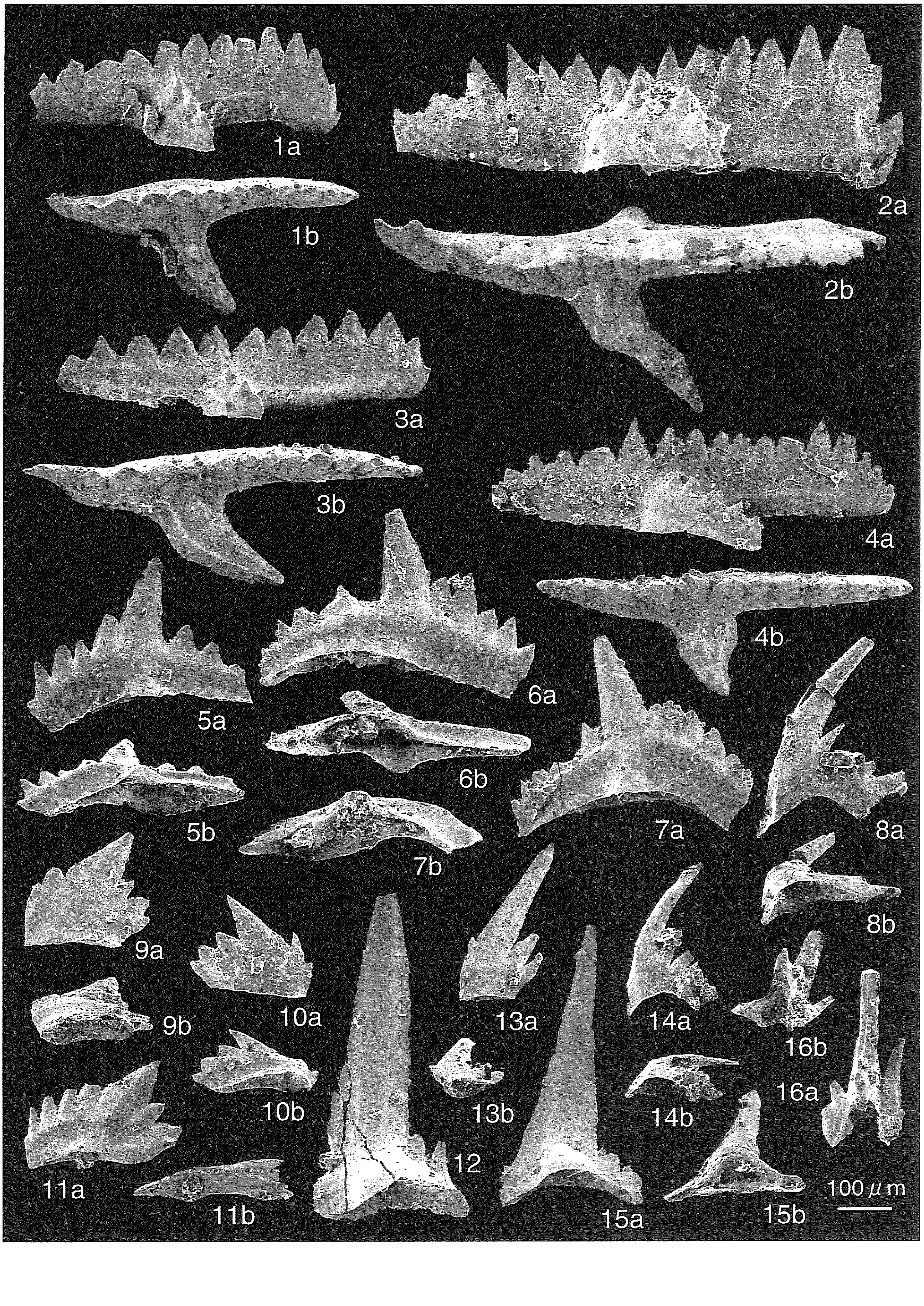
Explanation of Plate 50

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-15-- *Pterospathodus pennatus proceus* (Walliser, 1964)

1, lateral and oral views of *Pa* element, IGUT-ag2075, sample LAN-49.
2, lateral and oral views of *Pa* element, IGUT-ag2076, sample LAN-49.
3, lateral and oral views of *Pa* element, IGUT-ag2077, sample LAN-49.
4, lateral and oral views of *Pa* element, IGUT-ag2078, sample LAN-49.
5, lateral and aboral views of *Pb* element, IGUT-ag2079, sample LAN-49.
6, lateral and aboral views of *Pb* element, IGUT-ag2080, sample LAN-49.
7, lateral and aboral view of *Pb* element, IGUT-ag2081, sample LAN-50.
8, lateral and aboral views of *Sc2* element, IGUT-ag2082, sample LAN-49.
9, lateral and aboral view of *Pb2* element, IGUT-ag2083, sample LAN-49.
10, lateral and aboral views of *Pb2* element, IGUT-ag2084, sample LAN-49.
11, lateral and aboral views of *Pb2* element, IGUT-ag2085, sample LAN-50.
12, lateral view of *M1* element, IGUT-ag2086, sample LAN-49.
13, lateral and aboral views of *Sca* element, IGUT-ag2087, sample LAN-49.
14, lateral and aboral views of *Sca* element, IGUT-ag2088, sample LAN-49.
15, lateral and aboral views of *M1* element, IGUT-ag2089, sample LAN-50.
16, lateral and aboral views of *Sb2* element, IGUT-ag2090, sample LAN-49.

Plate 50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Explanation of Plate 51

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-4--*Panderodus langkawiensis* (Igo and Koike, 1967)

1, lateral and aboral views of *q* element, IGUT-ag2091, sample LAN-49.
2, lateral and aboral views of *q* element, IGUT-ag2092, sample LAN-49.
3, lateral and aboral views of *p* element, IGUT-ag2093, sample LAN-49.
4, lateral and aboral views of *p* element, IGUT-ag2094, sample LAN-49.

Figures 5-11--*Dapsilodus hamari* (Igo and Koike, 1967)

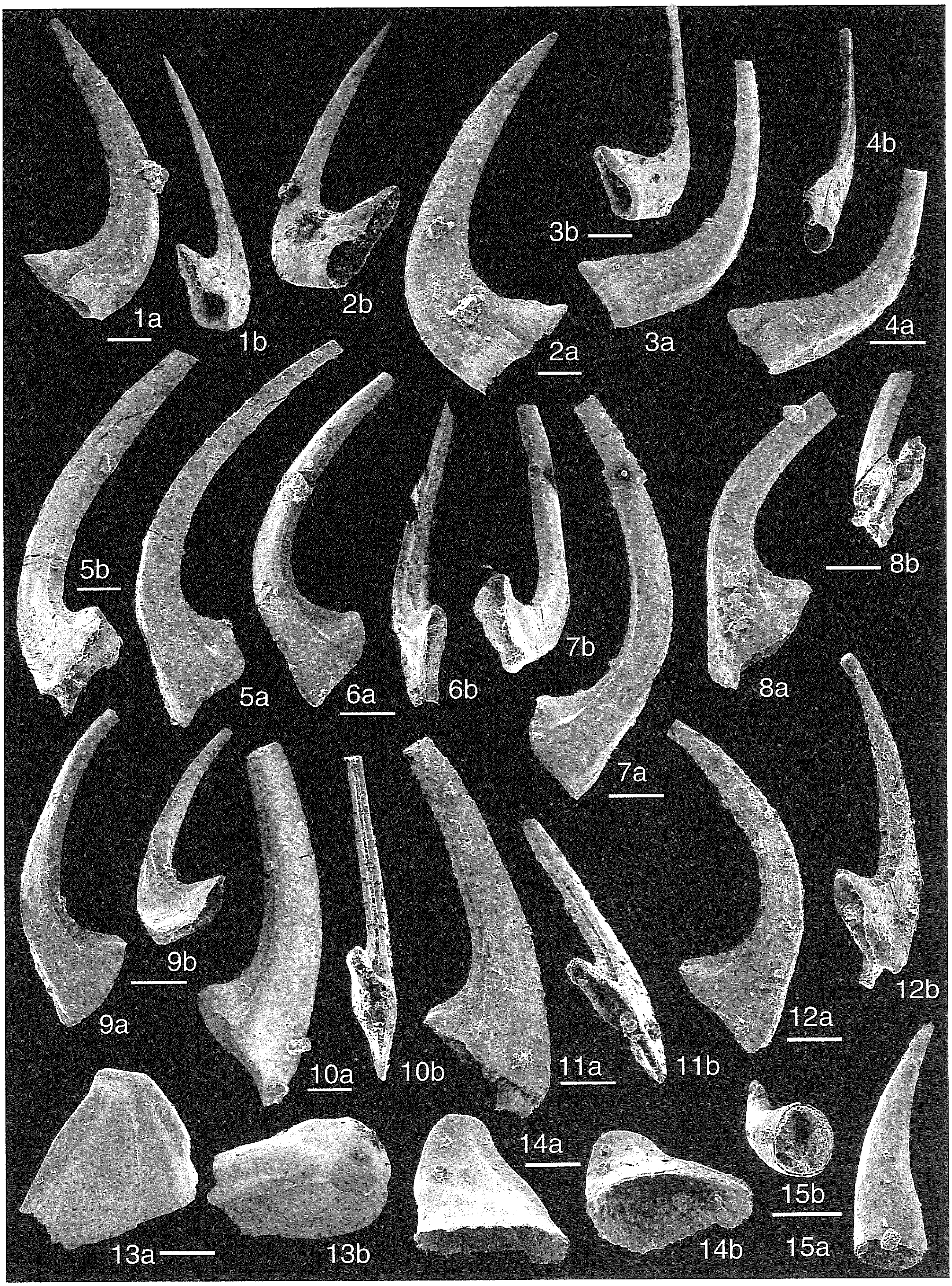
5, lateral and aboral views of *c* element, IGUT-ag2095, sample LAN-49.
6, lateral and aboral views of *c* element, IGUT-ag2096, sample LAN-49.
7, lateral and aboral views of *c* element, IGUT-ag2097, sample LAN-49.
8, lateral and aboral views of *b* element, IGUT-ag2098, sample LAN-49.
9, lateral and aboral views of *a* element, IGUT-ag2099, sample LAN-49.
10, lateral and aboral views of *e* element, IGUT-ag2100, sample LAN-49.
11, lateral and aboral views of *e* element, IGUT-ag2101, sample LAN-54.

Figure 12--*Dapsilodus praecipuus* Barrick, 1977

12, lateral and aboral views of *c* element, IGUT-ag2102, sample LAN-53.

Figures 13-15--*Pseudooneotodus* sp. A.

13, lateral and oral views of squat element, IGUT-ag2103, sample LAN-55.
14, lateral and aboral views of squat element, IGUT-ag2104, sample LAN-52.
15, lateral and aboral views of slender element, IGUT-ag2105, sample LAN-52.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Explanation of Plate 52

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-3--*Dapsilodus sparsus* Barrick, 1977

1, lateral and aboral views of *c* element, IGUT-ag2106, sample LAN-54.

2, lateral and aboral views of *a/b* element, IGUT-ag2107, sample LAN-54.

3, lateral and aboral views of *a/b* element, IGUT-ag2108, sample LAN-54.

Figures 4, 5--*Belodella resima* (Philip, 1965)

1, lateral and aboral views of *c* element, IGUT-ag2109, sample LAN-56.

2, lateral and aboral views of *b* element, IGUT-ag2110, sample LAN-56.

Figures 6-9--*Dapsilodus obliquicostatus* (Branson and Mehl, 1933)

6, lateral and aboral views of *c* element, IGUT-ag2111, sample LAN-52.

7, lateral and aboral views of *a/b* element, IGUT-ag2112, sample LAN-51.

8, lateral and aboral views of *c* element, IGUT-ag2113, sample LAN-52.

9, lateral and aboral views of *a/b* element, IGUT-ag2114, sample LAN-52.

Figures 10-12--*Panderodus unicostatus* (Branson and Mehl, 1933)

10, lateral and aboral views, IGUT-ag2115, sample LAN-49.

11, lateral and aboral views, IGUT-ag2116, sample LAN-49.

12, lateral and aboral views, IGUT-ag2117, sample LAN-49.

Figures 13-17--*Decoriconus fragilis* (Branson and Mehl, 1933)

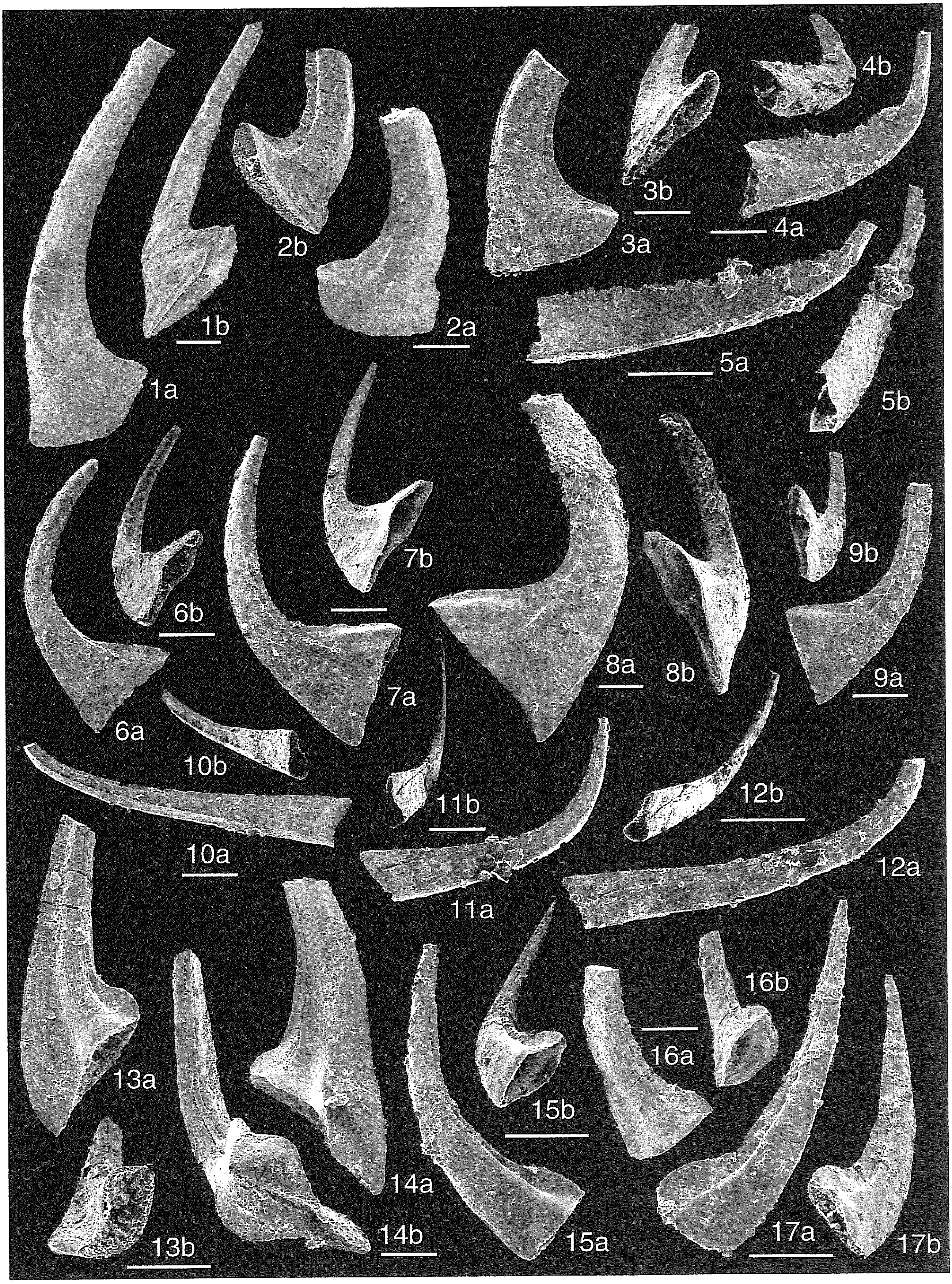
13, lateral and aboral views of *a* element, IGUT-ag2118, sample LAN-60.

14, lateral and aboral views of *a* element, IGUT-ag2119, sample LAN-60.

15, lateral and aboral views of *b* element, IGUT-ag2120, sample LAN-60.

16, lateral and aboral views of *c* element, IGUT-ag2121, sample LAN-60.

17, lateral and aboral views of *b* element, IGUT-ag2122, sample LAN-61.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Explanation of Plate 53

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1, 2--*Belodella anomalis* Cooper, 1974.
1, lateral and aboral views of *d* element, IGUT-ag2123, sample LAN-60.
2, lateral and aboral views of *f* element, IGUT-ag2124, sample LAN-60.

Figures 3-5--*Belodella devonica* Stauffer, 1940.
3, lateral and aboral views of *a* element, IGUT-ag2125, sample LAN-64.
4, lateral and aboral views of *c* element, IGUT-ag2126, sample LAN-64.
5, lateral and aboral views of *b* element, IGUT-ag2127, sample LAN-64.

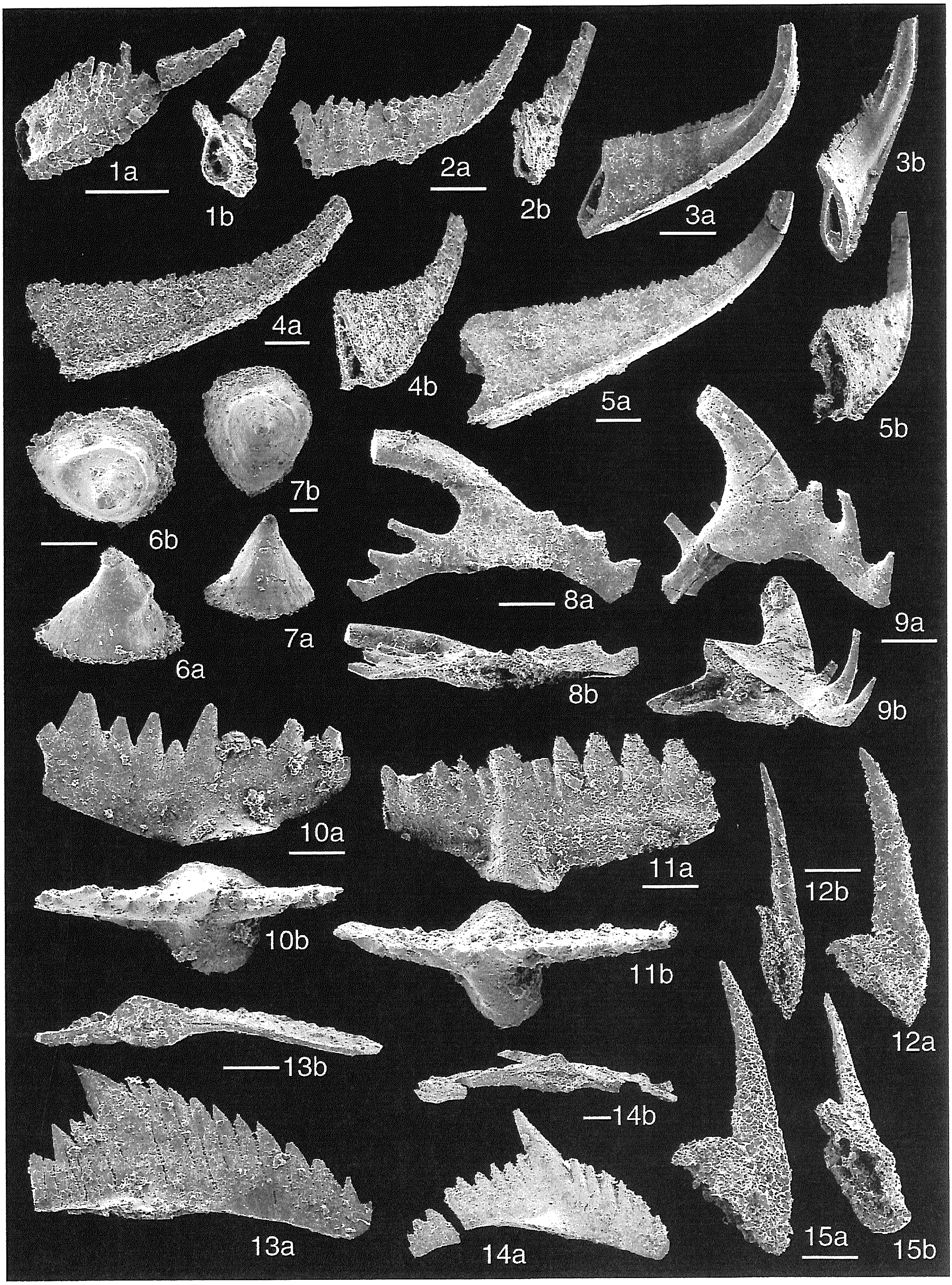
Figures 6, 7--*Pseudooneotodus beckmanni* (Bischoff and Sannemann, 1958).
6, lateral and oral views, IGUT-ag2128, sample LAN-64.
7, lateral and oral views, IGUT-ag2129, sample LAN-64.

Figures 8, 9--*Oulodus* sp. A.
8, lateral and aboral views, IGUT-ag2130, sample LAN-60.
9, lateral and aboral views, IGUT-ag2131, sample LAN-60.

Figures 10, 11, 13, 14--*Ozarkodina remscheidensis remscheidensis* (Zeigler, 1960).
10, lateral and oral views of *f* element, IGUT-ag2132, sample LAN-62.
11, lateral and oral views of *f* element, IGUT-ag2133, sample LAN-62.
13, lateral and aboral views of *g* element, IGUT-ag2134, sample LAN-64.
14, lateral and aboral views of *g* element, IGUT-ag2135, sample LAN-64.

Figures 12, 15--Gen. et sp. Indet. 5.
12, lateral and aboral views, IGUT-ag2136, sample LAN-61.
15, lateral and aboral views, IGUT-ag2137, sample LAN-61.

Plate 53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Explanation of Plate 54

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

Figures 1-5--*Ozarkodina remscheidensis eosteinhornensis* (Walliser, 1964).

1, lateral and oral views of *d* element, IGUT-ag2138, sample LAN-64.
2, lateral and oral views of *f* element, IGUT-ag2139, sample LAN-64.
3, lateral and oral views of *f* element, IGUT-ag2140, sample LAN-64.
4, lateral and aboral views of *g* element, IGUT-ag2141, sample LAN-64.
5, lateral and aboral views of *g* element, IGUT-ag2142, sample LAN-64.

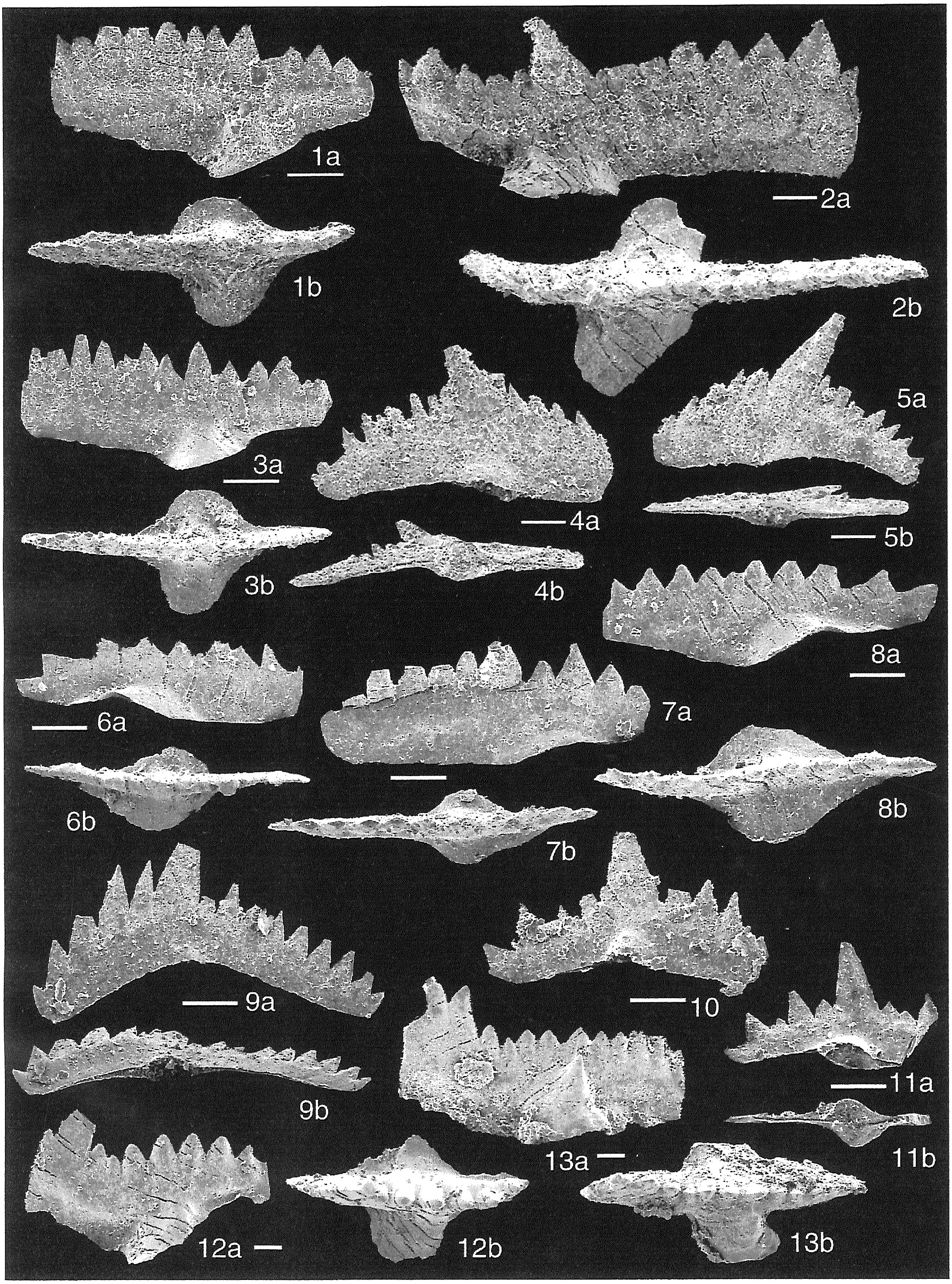
Figures 6-11--*Ozarkodina excavata excavata* (Branson and Mehl, 1933).

6, lateral and oral views of *d* element, IGUT-ag2143, sample LAN-65.
7, lateral and oral views of *f* element, IGUT-ag2144, sample LAN-65.
8, lateral and oral views of *f* element, IGUT-ag2145, sample LAN-65.
9, lateral and aboral views of *g* element, IGUT-ag2146, sample LAN-65.
10, lateral and aboral views of *g* element, IGUT-ag2147, sample LAN-65.
11, lateral and aboral views of *g* element, IGUT-ag2148, sample LAN-65.

Figures 12 ,13--*Pandorinella* sp. A.

12, lateral and oral views of *f* element, IGUT-ag2149, sample LAN-64.
13, lateral and oral views of *f* element, IGUT-ag2150, sample LAN-64.

Plate 54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Explanation of Plate 55

All figures are digital images of scanning electron microscope. Scale bar indicates 100 μm.

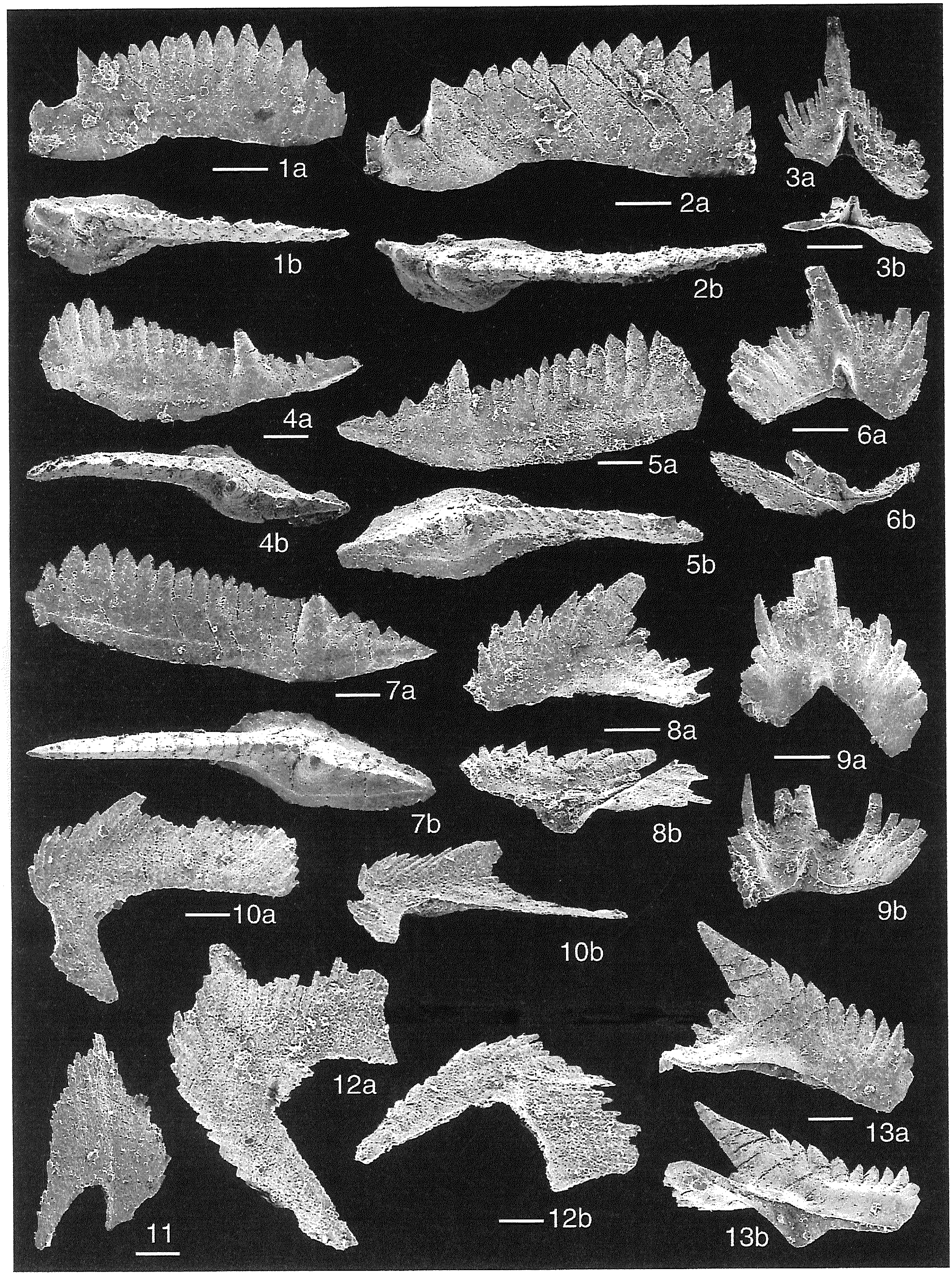
Figures 1, 2--*Flajsella stygia* (Flajs, 1967).
1, lateral and oral views of *d* element, IGUT-ag2151, sample LAN-65.
2, lateral and oral views of *f* element, IGUT-ag2152, sample LAN-65.

Figures 3, 6, 9--*Flajsella* sp. B.
3, lateral and aboral views of *a* element, IGUT-ag2153, sample LAN-65.
6, lateral and aboral views of *b* element, IGUT-ag2154, sample LAN-65.
9, lateral and aboral views of *a* element, IGUT-ag2155, sample LAN-65.

Figures 4, 5, 7--*Flajsella sigmostygia* Valenzuela-Ríos and Murphy, 1997.
4, lateral and oral views of *f* element, IGUT-ag2156, sample LAN-65.
5, lateral and oral views of *f* element, IGUT-ag2157, sample LAN-65.
7, lateral and oral views of *f* element, IGUT-ag2158, sample LAN-65.

Figures 8, 13--*Flajsella* sp. A.
8, lateral and aboral views of *g* element, IGUT-ag2159, sample LAN-65.
13, lateral and aboral views of *g* element, IGUT-ag2160, sample LAN-65.

Figures 10-12--Gen. et sp. Indet. 22.
10, lateral and aboral views of A element, IGUT-ag2161, sample LAN-65.
11, lateral view of B element, IGUT-ag2162, sample LAN-65.
12, lateral and aboral views of B element, IGUT-ag2163, sample LAN-65.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