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Late Devonian (Famennian) Conodonts from Denizliköyü, Gebze, Kocaeli, Northwestern Turkey

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Abstract: Late Devonian (Famennian) conodont faunas have been described from two incomplete stratigraphic sections (GD and GB) of the Ayineburnu member of the Tuzla formation, Denizliköyü, Gebze, Kocaeli, northwestern Turkey. The section GD comprises the Lower and Middle *expansa* Zones, and the section GB contains the Middle and Upper *expansa* Zones. Zonal indices for the Middle *expansa* Zone are identified in the section GB, whereas this zone is recognized on the basis of other key taxa in the section GD. Also, a new species of the Genus *Branmehla, Branmehla gediki* n.sp. is described from the section GD.

Key Words: Late Devonian (Famennian), conodont, Gebze, Kocaeli, Turkey.

Denizliköyü'nden (Gebze, Kocaeli, Kuzeybatı Türkiye) Geç Devoniyen (Fameniyen) Konodontları

Özet: Denizliköyü (Gebze, Kocaeli, kuzeybatı Türkiye), Paleozoyik yaşlı birimlerin yaygın olarak yüzeylendiği alanlardan birini oluşturur. Bu alandaki, genellikle sarımsı-kahve renkli yumrulu ve ince katmanlı kireçtaşlarından oluşan, kil-marn araseviyeleri ile özellikle üst kısımlarında daha yaygın olan koyu gri renkli çok ince çört bantları ve yumruları içeren birim, Ayineburnu üyesi olarak bilinir. Tuzla Formasyonu'nun en üst üyesi olan bu birime ait iki eksik stratigrafik kesitten (GD ve GB), pelajik fasiyesi temsil eden, Fameniyen (Geç Devoniyen) yaşlı konodont faunaları tanımlanmış ve bu faunalar yardımıyla, incelenen stratigrafik kesitler Geç Devoniyen standart konodont zonlaması ile deneştirilmiştir. Yaklaşık 20 metre kalınlıktaki GD kesiti, Alt ve Orta *expansa* Zonlarını; 11 metre kalınlıktaki GB kesiti, Orta ve Üst *expansa* Zonlarını içerir. GD kesitindeki Orta *expansa* Zonu'nun alt sınırı, zon belirleyici takson *Bispathodus aculeatus*'un yokluğu nedeniyle diğer anahtar taksonlar yardımıyla belirlenmiştir. İki kesitten, 6 cinse ait toplam 34 konodont tür ve alttürü tanımlanmıştır. GD kesitinden elde edilen taksonlardan biri, yeni tür olarak (*Branmehla gediki* n.sp.) tanıtılmıştır.

Anahtar Sözcükler: Geç Devoniyen (Fameniyen), konodont, Gebze, Kocaeli. Türkiye.

Introduction

For the Late Devonian, two conodont zonations, based on different biofacies, have been proposed: the standard conodont zonation (Ziegler, 1962; Ziegler & Sandberg 1984, 1990), and the nearshore conodont zonation (Sandberg & Dreesen 1984). The standard Late Devonian conodont zonation, based on the pelagic facies, has a widespread applicability. However, the alternative shallow-water conodont zonation, defined from nearshore facies, is applicable only locally. The Late Devonian, subdivided into 32-mainly *Palmatolepis*-based-zones in the standard conodont zonation (Ziegler & Sandberg 1990), has been subdivided into nine icriodontid-based zones in the nearshore conodont zonation (Sandberg & Dreesen 1984).

In Turkey, the Upper Devonian rocks of the pelagic facies are known only from the "İstanbul Terrane" (Kozur & Göncüoğlu 1999), and are represented generally by the Ayineburnu Member of the Tuzla Formation. The typical outcrops of this member are exposed on Büyükada and on the Tuzla Peninsula, İstanbul, and around Gebze, Kocaeli, northwestern Turkey (Figure 1). It has a complete section neither at its type locality on the Tuzla Peninsula nor at other localities because of folding and intense faulting. A complete stratigraphic section can only be reconstructed by joining up small sections from many separate localities. The Ayineburnu section in the southwestern part of Büyükada, İstanbul, has been investigated by Çapkınoğlu (1997) and the Upper *rhomboidea* and Lower *marginifera* Zones have been recognized.

The faunas examined in this study were obtained from two incomplete sections (GD and GB) that are situated near Denizliköyü, approximately 20 km northeast of Gebze, Kocaeli, northwestern Turkey (Figure 1). A total of 51 samples were collected from two localities. Of these, 40 yielded conodont faunas.

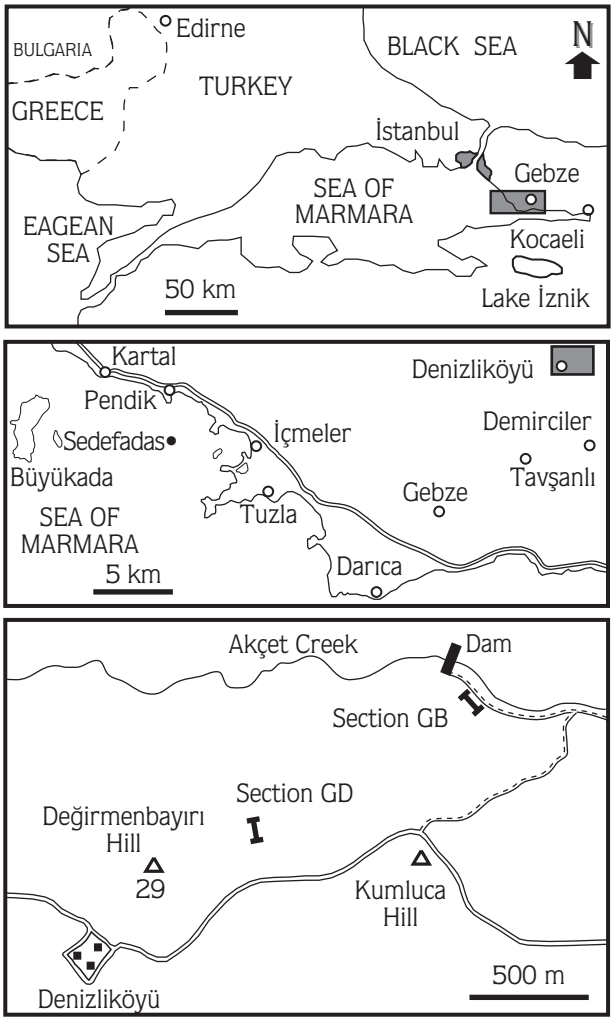

Figure 1. Location maps showing studied sections (GD and GB) and adjacent areas.

Locality of Sections and Lithostratigraphy

The "Palaeozoic of İstanbul" comprises two different terranes with very different Paleozoic-Mesozoic histories: the İstanbul Terrane (Palaeozoic-Mesozoic sequence around İstanbul-Gebze) and the Zonguldak Terrane (Çamdağ, Zonguldak, Amasra and Safranbolu regions) (Kozur & Göncüoğlu 1999). The İstanbul Terrane was affected only by the Hercynian and Alpine orogenies in contrast with the Zonguldak Terrane that was also affected by the Caledonian orogeny. The studied sections (GD and GB) are within the İstanbul Terrane and belong to the upper part of the Ayineburnu member, the uppermost member of the Tuzla Formation. These sections are located near Denizliköyü, about 20 km northeast of Gebze, Kocaeli, northwestern Turkey (Figure 1). Section GD is about 900 m northeast of Denizliköyü, and crops out about 175 m north of the Gebze-Denizliköyü highway and about 450 m northeast of Değirmenbayırı Hill. The thickness of this section is 20.25 meters. The lower boundary is concealed, and the upper boundary is both faulted and covered. Section GB, farther from the Gebze-Denizliköyü highway, is a roadside exposure, located about 2 km northeast of Denizliköyü, approximately 100 m southeast of the dam on Akçet Creek. The thickness is 11 meters. The lower contact is a fault and the upper contact is covered by colluvium. The lithology consists mainly of grey-beige, yellow-beige, grey and light-grey, generally thin-bedded, nodular to evenly bedded mudstone-wackestone, and grey to beige, laminated shale and marl. Dark grey chert nodules, lenses and bands are also present (Figure 2). Although some samples are either barren of or are very poor in conodonts, many of them yielded very abundant ostracod fauna. A few trilobite fragments and brachiopod shells were also obtained from some samples as residue following treatment with acid.

Conodont Biostratigraphy

Three Late Devonian conodont zones (Ziegler & Sandberg 1984) have been recognized in the studied sections (GD and GB) of the Tuzla Formation. The section GD is divisible into Lower and Middle *expansa* Zones, and the section GB comprises the Middle and Upper *expansa* Zones (Figure 2, Tables 1 & 2).

Lower expansa Zone

The Lower *expansa* Zone has been recognized in the lower part of section GD (Figure 2, Table 1). Its base is defined on the basis of the lowest occurrence of *Palmatolepis gracilis expansa* by Ziegler & Sandberg (1984). However, only one fragmentary specimen of this species was found in sample GD5 (Table 1). Also, the zonal index for the upper boundary, *Bispathodus aculeatus,* is absent. Therefore the recognition of this

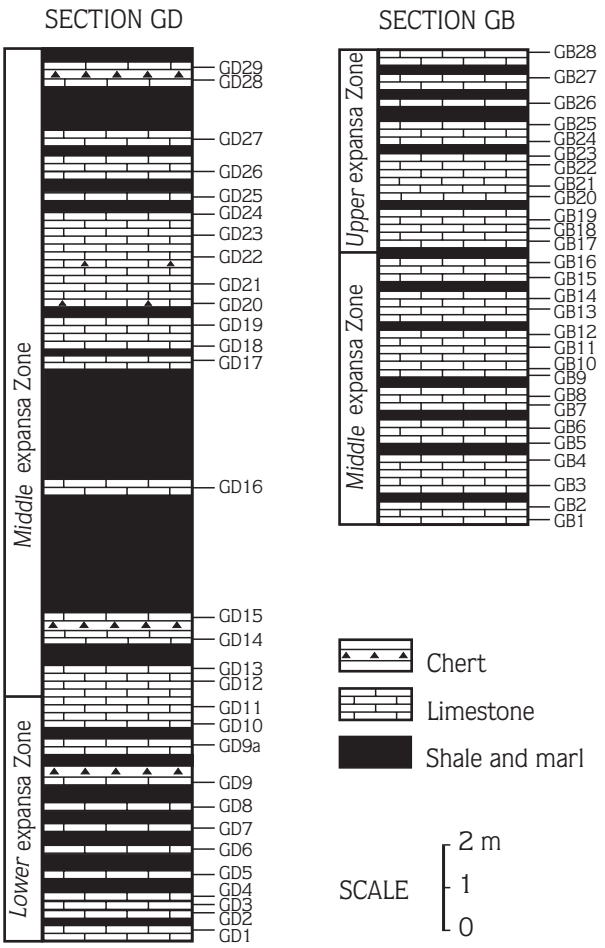

Figure 2. Stratigraphic columns of the sections (GD and GB) examined. Sample numbers are indicated along the right side of each column.

zone has been based on the occurrence of *Polygnathus styriacus*. Sample GD11 is within the Lower *expansa* Zone because it contains the highest occurrence of *Polygnathus styriacus,* which disappears at the end of the Lower *expansa* Zone (Ziegler & Sandberg 1984, Fig. 2). Also, the lowest sample (GD1) belongs to the Lower *expansa* Zone due to the occurrence of *Bispathodus stabilis* Morphotype 2, which first appears at the base of the Lower *expansa* Zone (Ziegler & Sandberg 1984, Fig. 4). Therefore, the beds with *Polygnathus styriacus* in section GD represent the Lower *expansa* Zone (Table 1, samples GD1-GD11).

Middle expansa Zone

The Middle *expansa* Zone is present in both sections. The base of this zone is defined on the lowest occurrence of *Bispathodus aculeatus* by Ziegler & Sandberg (1984). This taxon is absent in section GD. Therefore, the lower boundary is defined by the last occurrence of *Polygnathus styriacus* in sample GD11. In addition, based on the absence of *Bispathodus ultimus*, the defining taxon of the upper boundary, overlying beds are also assigned to the Middle *expansa* Zone (Table 1, samples GD12-GD29).

The Middle *expansa* Zone is represented by samples GB2-GB16 in the lower part of section GB (Table 2). The lowest sample (GB2) of this section is within the Middle *expansa* Zone based on the occurrence of *Bispathodus aculeatus aculeatus*. Sample GB17 contains the lowest occurrence of *Bispathodus ultimus* defining the upper boundary of the Middle *expansa* Zone (Ziegler & Sandberg 1984, p. 184). Therefore, the beds below the lowest occurrence of *Bispathodus ultimus* belong to the Middle *expansa* Zone.

Upper expansa Zone

The Upper *expansa* Zone is represented by samples GB17-GB22 in the upper part of section GB (Figure 2, Table 2). Sample GB17 contains the lowest occurrence of *Bispathodus ultimus,* the zonal index for the base of the Upper *expansa* Zone (Ziegler & Sandberg 1984, p. 184); therefore, it is within the Upper *expansa* Zone. In addition, the stratigraphically higher samples are also assigned to this zone due to the absence of *Siphonodella praesulcata* that defines the base of the overlying *praesulcata* Zone.

Systematic Paleontology

The familial classification proposed by Sweet (1988) is used in this report. Conodonts discussed herein (Table 1 & 2) belong to the Palmatolepidae, Polygnathidae and Spathognathodontidae families. Platform elements are the focus of this study, although ramiform elements are also present. Illustrated specimens and faunal slides are reposited at Karadeniz Teknik Universitesi in the Jeoloji Mühendisliği Bölümü, Trabzon, Turkey.

Family PALMATOLEPIDAE Sweet, 1988

Genus *Palmatolepis* ULRICH & BASSLER, 1926

Type species.- *Palmatolepis perlobata* ULRICH & BASSLER, 1926

Table 1. Distribution and abundance of Pa elements of conodont taxa defined from the GD section. See Figure 2 for sample intervals. ? indicates questionable identification. Abbreviations: *Pa. = Palmatolepis, Po. = Polygnathus, Ps. = Pseudopolygnathus.*

CONODONT ZONE	Lower *expansa*											Middle *expansa*											
SAMPLE NUMBER (GD)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	20	22	24	25	27	29
SAMPLE WEIGHT (Kg)	.80	.55	.90	.90	1.2	1.0	.90	1.2	1.2	1.1	.95	.85	1.0	1.0	1.0	1.1	.85	1.1	1.35	1.1	1.0	1.1	.90
Pa. gracilis expansa					1																		
Pa. gracilis gracilis	2	3		5	4			4	9	5	2		1	1	1	1		1		3	2	3	
Pa. gracilis manca		1		3																			
Pa. gracilis sigmoidalis		3	1	6	1	2	3	4	17	7	3	2		1	4	1	7	12	2	10	2	1	
Pa. perlobata postera								2?	1								1			6			
Pa. perlobata schindewolfi				6	5			1	8	2	3			1	4	1	2	1		3			
Pa. rugosa ampla				1	5					1					1								
Pa. rugosa rugosa													1		1	1	1			2			
Po. communis communis							1?		1			2										2	1
Po. marginvolutus							1		4	5	2		3		21								
Po. perplexus													1?		3			1					
Po. rhabdotus																						2	
Po. aff. *semicostatus*					2				7				1		1								
Po. styriacus	4	4		8	3	1	7	3	19		1												
Po. aff. *subirregularis*				2																			
Po. znepolensis																1		3					
Ps. cf. *dentilineatus*																				1			
Ps.? kayseri																						2	
Ps. micropunctatus																				15			
Bispathodus jugosus																					6		
Bispathodus stabilis M1	1	2		10	4				7			1					21	4		3	5	4	
Bispathodus stabilis M2	1																					2	
Branmehla bohlenana					2			1															
Branmehla fissilis																		2					
Branmehla gediki n. sp.		2		3	4	3	22		8	1	1?			1			1?						
Branmehla inornata		3				1		1?	4	2	4	5	1		4	1	11	7	2	28	10		
Mehlina strigosa	21	1		4	1			3	30	42	22	8	1	6	17			3		8	3	7	

Palmatolepis gracilis expansa SANDBERG & ZIEGLER, 1979

Plate 1, Figure 4

1979 *Palmatolepis gracilis expansa* SANDBERG & ZIEGLER, p. 178, Pl. 1, Figs. 6-8 (see synonymy).

Remarks: The rather wide rimless platform of the Pa element has a small outer lobe.

Occurrence: Section GD (Table 1).

Material: 1 Pa element.

Palmatolepis gracilis gracilis BRANSON & MEHL, 1934a

Plate 1, Figures 15-18

1934a *Palmatolepis gracilis* BRANSON & MEHL, p. 238, Pl. 18, Fig. 8 (only).

1997 *Palmatolepis gracilis gracilis* BRANSON & MEHL.-ÇAPKINOĞLU, p. 170, Pl. 2, Figs. 16-18 (see synonymy).

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: 58 Pa elements.

Table 2. Distribution and abundance of Pa elements of conodont taxa defined from the GB section. See Figure 2 for sample intervals. Abbreviations: *Pa. = Palmatolepis, Po. = Polygnathus, Ps. = Pseudopolygnathus.*

CONODONT ZONE	Middle *expansa*												Upper *expansa*				
SAMPLE NUMBER (GB)	2	3	4	6	7	9	10	11	12	14	15	16	17	18	19	21	22
SAMPLE WEIGHT (Kg)	1.1	.70	1.1	.95	.90	1.0	.85	1.0	1.0	1.0	1.0	.75	.90	.65	1.0	.85	.95
Pa. gracilis gracilis	3		1		1		2	1					3			1	1
Pa. gracilis sigmoidalis	2	3	3		2	2	1	1	4		23	2	26	15	57	2	7
Po. communis communis			1								1				1		
Po. marginvolutus							1										
Ps. m. marburgensis										1					1		
Ps. m. trigonicus													4		9		1
Ps. micropunctatus									1								
*Ps.*cf. *dentilineatus*			1		1		1		1	1	1						
Branmehla inornata	5	2	6			1	1			2	4		2	1	1	3	1
Bispathodus a. aculeatus	1																
Bispathodus bispathodus	1																
Bispathodus cf. *costatus*													6		2		
Bispathodus cf. *spinulicostatus*															*2*		
Bispathodus stabilis M1	1		3	1					1		2		2				
Bispathodus stabilis M2	1														3		
Bispathodus ultimus M1													1				
Bispathodus ultimus M2													1				
Mehlina strigosa	1	2									3		2	2	7	3	

Palmatolepis gracilis manca HELMS, 1963

Plate 1, Figure 20

1963 *Palmatolepis (Pand.) distorta manca* HELMS, p. 467-468, Pl. 2, Figs. 22, 27; Pl. 3, Figs. 14, 15; text - Fig. 2, Fig. 27.

1979 *Palmatolepis gracilis manca* HELMS.- SANDBERG & ZIEGLER, p. 178, Pl. 1, Figs. 10-14.

Remarks: A strongly curved blade-carina, and a bulge parallel to the blade on the outer platform are the most diagnostic features of the Pa element of this subspecies.

Occurrence: Section GD (Table 1).

Material: 4 Pa elements.

Palmatolepis gracilis sigmoidalis ZIEGLER, 1962

Plate 1, Figures 12-14

1962 *Palmatolepis deflectens sigmoidalis* ZIEGLER, p. 56-57, Pl. 3, Figs. 24-28.

1977 *Palmatolepis gracilis sigmoidalis* ZIEGLER.- ZIEGLER, p. 323-324, *Palmatolepis* - Pl. 7, Figs. 13-16 (see synonymy).

Remarks: The most distinguishing characteristic of the Pa element is the bizarre twisting of its platform and blade-carina. Platform is much smaller than that of *Palmatolepis gracilis gracilis*.

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: 234 Pa elements.

Palmatolepis perlobata postera ZIEGLER, 1960

Plate 1, Figures 1-3

1960 *Palmatolepis rugosa postera* ZIEGLER, Pl. 2, Figs. 10-11.

1979 *Palmatolepis perlobata postera* ZIEGLER.– SANDBERG & ZIEGLER, p. 180, Pl. 2, Figs. 1-4 (see synonymy).

Remarks: The Pa element has a slightly to moderately upflexed posterior platform, the outer half of which is ornamented with nodes that are arranged in rows parallel to the platform margin, and a rounded parapet that is ornamented with coarser nodes.

Occurrence: Section GD (Table 1).

Material: 8 Pa elements and 2 questionable specimens.

Palmatolepis perlobata schindewolfi MÜLLER, 1956

Plate 1, Figure 5

1956 *Palmatolepis (Palmatolepis) schindewolfi* MÜLLER, p. 27-28, Pl. 8, Figs. 22-31; Pl. 9, Fig. 33.

1997 *Palmatolepis perlobata schindewolfi* MÜLLER.- ÇAPKINOĞLU, p. 172, Pl. 4, Figs. 23-26 (see synonymy).

Occurrence: Section GD (Table 1).

Material: 36 Pa elements.

Palmatolepis rugosa ampla MÜLLER, 1956

Plate 1, Figures 6-7

1956 *Palmatolepis (Palmatolepis) ampla* MÜLLER, p. 28-29, Pl. 9, Figs. 35-36.

1979 *Palmatolepis rugosa ampla* MÜLLER.– SANDBERG & ZIEGLER, p. 181, Pl. 2, Figs. 10-11 (see synonymy).

Remarks: The Pa element of this subspecies has many random small nodes or many weak cross ridges formed by a row of nodes in the parapet area and a longitudinal row of larger nodes on the anterior outer platform. Some specimens are transitional to *Palmatolepis rugosa rugosa*. They generally have a more and weaker cross ridges, which are formed by fusion of small nodes.

Occurrence: Section GD (Table 1).

Material: 8 Pa elements.

Palmatolepis rugosa rugosa BRANSON & MEHL, 1934a

Plate 1, Figures 8-9

1934a *Palmatolepis rugosa* BRANSON & MEHL, p. 236, Pl. 18, Figs. 15-16, 18-19.

1979 *Palmatolepis rugosa rugosa* BRANSON & MEHL.- SANDBERG & ZIEGLER, p. 181, Pl. 2, Figs. 5-7 (see synonymy).

Remarks: A parapet area ornamented with sharp cross ridges or very coarse nodes, a longitudinal row of very coarse nodes on the anterior outer platform that forms an acute angle with the blade, and a nearly right row of very coarse nodes on the anterior edge of the strong outer lobe are characteristic features of the Pa element.

Occurrence: Section GD (Table 1).

Material: 6 Pa elements.

Family POLYGNATHIDAE Bassler, 1925

Genus *Polygnathus* HINDE, 1879

Type species.- *Polygnathus dubius* HINDE, 1879

Polygnathus communis communis BRANSON & MEHL, 1934b

Plate 2, Figures 15-16

1934b *Polygnathus communis* BRANSON & MEHL, p. 293, Pl. 24, Figs. 1-4.

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: 9 Pa elements and 1 questionable specimen.

Polygnathus marginvolutus GEDİK, 1969

Plate 2, Figures 17-21

1969 *Polygnathus marginvolutus* GEDİK, p. 237, Pl. 5, Figs. 2-8.

1991 *Polygnathus marginvolutus* GEDİK.- PERRI & SPALLETTA, p. 71, Pl. 6, Figs. 1-2 (see synonymy).

Remarks: The Pa element has a triangular platform with upturned margins, deepening anteriorly and shallowing posteriorly, and generally scalloped anterior platform margins, characteristic of the species. The posterior part of the platform bears weak transverse ridges not reaching the carina.

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: 37 Pa elements.

Polygnathus perplexus THOMAS, 1949

Plate 2, Figures 1-3

1949 *Polygnathus perplexa*? THOMAS, p. 418-419, Pl. 2, Fig. 23.

1989 *Polygnathus perplexus* THOMAS.- METZGER, p. 520-521, Figs. 15.12-15.14, 15.25 (see synonymy).

Remarks: Although the present Pa elements conform to the description of *Polygnathus experplexus* given by Sandberg & Ziegler (1979), they are assigned to this species due to the criteria indicated by Metzger (1989).

Occurrence: Section GD (Table 1).

Material: 4 Pa elements and 1 questionable specimen.

Polygnathus rhabdotus SCHÄFER, 1976

Plate 2, Figure 6

1976 *Polygnathus rhabdotus* SCHÄFER, p. 146, Pl. 1, Figs. 18-22.

Remarks: The Pa element has some resemblance to *Polygnathus pennatulus* in outline but that species has a platform ornamentation consisting of a row of aligned nodes.

Occurrence: Section GD (Table 1).

Material: 2 Pa elements.

Polygnathus aff. *semicostatus* BRANSON & MEHL, 1934a

Plate 2, Figures 11-13

Remarks: The Pa elements are similar to those of *Polygnathus semicostatus* Morphotype 1 and 2 of Sandberg & Ziegler (1979). However, because they are relatively small and poorly preserved, the identification is considered uncertain.

Occurrence: Section GD (Table 1).

Material: 11 Pa elements.

Polygnathus styriacus ZIEGLER, 1957

Plate 2, Figures 8-10

1957 *Polygnathus styriaca* ZIEGLER, p. 47-48, Pl. 1, Figs. 12-13 (not Fig. 11 = *P. vogesi*).

1979 *Polygnathus styriacus* ZIEGLER.- SANDBERG & ZIEGLER, p. 186-187, Pl. 4, Figs. 14-18.

Remarks: The present Pa elements consist of the juvenile and adult forms. As indicated by Sandberg & Ziegler (1979), the upper surface of the juvenile Pa elements are generally unornamented except for a small diagonal row of nodes in the anterior part of the platform. This diagonal row of nodes, and the nearly completely concave lower surface, similar to that of the adult specimens, are the most distinguishing characteristics of these juvenile specimens. The adult specimens have upper platform surfaces ornamented with small nodes.

Occurrence: Section GD (Table 1).

Material: 50 Pa elements.

Polygnathus aff. *subirregularis* SANDBERG & ZIEGLER, 1979

Plate 2, Figure 14

Remarks: The Pa elements of this species differ from those of *Polygnathus subirregularis* in having a shorter and wider platform with a shorter posterior platform tongue, and a more continuous posterior carina.

Occurrence: Section GD (Table 1).

Material: 2 Pa elements.

Polygnathus znepolensis SPASSOV, 1965

Plate 2, Figure 7

1965 *Polygnathus znepolensis* SPASSOV, Pl. 3, Figs. 1-2.

1991 *Polygnathus znepolensis* SPASSOV.- PERRI & SPALLETTA, p. 73, Pl. 7, Figs. 6-7 (see synonymy).

Remarks: Nearly rectangular or parallelogram-like platform of the Pa element has a broad, smooth outer side with a scalloped margin, and a narrower inner side bearing oblique ridges.

Occurrence: Section GD (Table 1).

Material: 4 Pa elements.

Family SPATHOGNATHODONTIDAE Hass, 1959

Genus *Bispathodus* MÜLLER, 1962

Type species.- *Spathodus spinulicostatus* BRANSON, 1934

Bispathodus aculeatus aculeatus (BRANSON & MEHL, 1934a)

Plate 3, Figure 5

1934a *Spathodus aculeatus* BRANSON & MEHL, p. 186-187, Pl. 17, Figs. 11, 14.

1974 *Bispathodus aculeatus aculeatus* (BRANSON & MEHL).- ZIEGLER, SANDBERG & AUSTIN, p. 101, Pl. 1, Fig. 5; Pl. 2, Figs. 1-8.

Occurrence: Section GB (Table 2).

Material: 1 Pa element.

Bispathodus bispathodus ZIEGLER, SANDBERG & AUSTIN, 1974

Plate 3, Figure 10

1974 *Bispathodus bispathodus* ZIEGLER, SANDBERG & AUSTIN, p. 102, Pl. 3, Figs. 4-12, 17, 21.

Occurrence: Section GB (Table 2).

Material: 1 Pa element.

Bispathodus cf. *costatus* (BRANSON, 1934)

Plate 3, Figures 11-12

Remarks: The Pa elements are similar, in upper view, to *Bispathodus aculeatus aculeatus*, but have a *bispathodus*-like basal cavity that reaches the posterior tip of the blade as in *Bispathodus costatus* Morphotype 1. Lateral nodes or transverse ridges on the right side of the blade do not reach the posterior tip.

Occurrence: Section GB (Table 2).

Material: 8 Pa elements.

Bispathodus jugosus (BRANSON & MEHL, 1934a)

Plate 3, Figures 1-4

1934a *Spathodus jugosus* BRANSON & MEHL, p. 190-191, Pl. 17, Figs. 19, 22(?).

1974 *Bispathodus jugosus* (BRANSON & MEHL).- ZIEGLER, SANDBERG & AUSTIN, p. 103, Pl. 1, Figs. 3, 4; Pl. 3, Figs. 19, 23, 26.

Remarks: The present Pa elements strongly resemble *Bispathodus costatus*, but they have been assigned to this species because of presence of a few germ denticles inserted between the main- and lateral-row denticles.

Occurrence: Section GD (Table 1).

Material: 6 Pa elements.

Bispathodus cf. *spinulicostatus* (BRANSON, 1934)

Plate 3, Figure 17

Remarks: The Pa elements are similar to *Bispathodus spinulicostatus*. However, they can not be confidently assigned to this species.

Occurrence: Section GB (Table 2).

Material: 2 Pa elements.

Bispathodus stabilis (BRANSON & MEHL, 1934a)

Plate 4, Figures 12-16

1934a *Spathodus stabilis* BRANSON & MEHL, p. 188-189, Pl. 17, Fig. 20.

1975 *Bispathodus stabilis* (BRANSON & MEHL).- ZIEGLER, p. 47-49, *Bispathodus* - Pl. 2, Figs. 9-12.

Remarks: Three morphotypes of this species have been differentiated (Ziegler *et al.* 1974; Sandberg & Ziegler 1979). The Pa elements of this study include Morphotypes 1 and 2 of Ziegler *et al.* (1974). Many Pa elements correspond to Morphotype 1 with relatively small, symmetrical basal cavities that do not extend to the posterior ends. A few specimens, which have wider, slightly asymmetrical basal cavities reaching the posterior tips, represent Morphotype 2.

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: Morphotype 1: 72 Pa elements and Morphotype 2: 7 Pa elements.

Bispathodus ultimus (BISCHOFF, 1957)

Plate 3, Figures 16, 18

1957 *Spathognathodus ultimus* BISCHOFF, p. 57-58, Pl. 4, Fig. 24-26.

1984 *Bispathodus ultimus* (BISCHOFF). – ZIEGLER & SANDBERG, p. 186-187, Pl. 2, Figs. 1-7 (see synonymy).

Remarks: Ziegler & Sandberg (1984) described two morphotypes of this species. The present specimens contain both morphotypes.

Occurrence: Section GB (Table 2).

Material: Morphotype 1: 1 Pa element and Morphotype 2: 1 Pa element.

Genus *Mehlina* YOUNGQUIST, 1945

Type species - *Mehlina irregularis* YOUNGQUIST, 1945 (= *Mehlina gradata* YOUNGQUIST, 1945)

Mehlina strigosa (BRANSON & MEHL, 1934a)

Plate 4, Figures 19-21

1934a *Spathodus strigosus* BRANSON & MEHL, p. 187, Pl. 17, Fig, 17.

1997 *Mehlina strigosa* (BRANSON & MEHL). – ÇAPKINOĞLU, p. 182-183, Pl. 4, Figs. 3-7 (see synonymy).

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: 197 Pa elements.

Genus *Pseudopolygnathus* BRANSON & MEHL, 1934b

Type species. – *Pseudopolygnathus primus* BRANSON & MEHL, 1934b

Pseudopolygnathus cf. *dentilineatus* BRANSON, 1934 (sensu SANDBERG & ZIEGLER, 1979)

Plate 4, Figures 17-18

1979 *Pseudopolygnathus* cf. *dentilineatus* BRANSON – SANDBERG & ZIEGLER, p. 183-184, Pl. 3, Figs. 18-21.

Remarks: The Pa elements consist mainly of juvenile specimens.

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: 7 Pa elements.

Pseudopolygnathus? kayseri BISCHOFF & ZIEGLER, 1956

Plate 2, Figures 4-5

1956 *Pseudopolygnathus? kayseri* BISCHOFF & ZIEGLER, p. 162, Pl. 11, Figs. 3-6.

Remarks: The Pa element of this species has an oval, slightly asymmetrical platform, ornamented with small nodes arranged in faint transverse ridges. The basal pit is asymmetrical and centrally located.

Occurrence: Section GD (Table 1).

Material: 2 Pa elements.

Pseudopolygnathus marburgensis marburgensis BISCHOFF & ZIEGLER, 1956

Plate 3, Figure 7

1956 *Pseudopolygnathus marburgensis* BISCHOFF & ZIEGLER, p. 162-163, Pl. 11, Figs. 9, 11-13.

1979 *Pseudopolygnathus marburgensis marburgensis* BISCHOFF & ZIEGLER.– SANDBERG & ZIEGLER, p. 182, Pl. 3, Figs. 1-4.

Remarks: The distinction between Pa elements of *Pseudopolygnathus marburgensis marburgensis* and *Pseudopolygnathus marburgensis trigonicus* is based on the details of the lower surface in addition to the upper surface ornamentation as in Klapper (1981, p. 381), and specimens with a restricted development of the basal cavity are assigned to *Pseudopolygnathus marburgensis trigonicus*.

Occurrence: Section GB (Table 2).

Material: 2 Pa elements.

Pseudopolygnathus marburgensis trigonicus ZIEGLER, 1962

Plate 3, Figures 8-9

1962 *Pseudopolygnathus trigonica* ZIEGLER, p. 101-102, Pl. 12, Figs. 8-13.

1970 *Pseudopolygnathus trigonica* ZIEGLER. – SEDDON, p. 63-64, Pl. 9, Figs. 8-11.

Occurrence: Section GB (Table 2).

Material: 14 Pa elements.

Pseudopolygnathus micropunctatus BISCHOFF & ZIEGLER, 1956

Plate 1, Figure 19

1956 *Pseudopolygnathus micropunctata* BISCHOFF & ZIEGLER, p. 163-164, Pl. 11, Figs. 7, 8, 10.

Remarks: The anterior outer lobes of the present Pa elements vary from strongly to faintly developed. The forms lacking a strong anterior outer lobe are described as *Pseudopolygnathus* cf. *micropunctatus* by Sandberg & Ziegler (1979). However, according to Klapper (1981), and Perri & Spalletta (1991), they are within the range of variation of *Pseudopolygnathus micropunctatus*.

Occurrence: Sections GD and GB (Table 2).

Material: 16 Pa elements.

Family Unknown

Genus *Branmehla* HASS, 1959

Type species.- *Spathodus inornatus* BRANSON & MEHL, 1934a

Branmehla bohlenana (HELMS, 1959)

Plate 4, Figures 7-10

1959 *Spathognathodus bohlenanus* HELMS, p. 658, Pl. 6, Figs. 5-8.

1962 *Spathognathodus bohlenanus* HELMS.- ZIEGLER, p. 106, Pl. 12, Figs. 25, 26, 29-35.

1967 *Spathognathodus bohlenanus* HELMS.- WOLSKA, p. 426, Pl. 18, Figs. 4-6.

Remarks: The posterior process with approximately 1/3 element length is slightly flexed inward and downward. The asymmetrical basal cavity is relatively short and wide, restricted to the anterior part of the posterior half of the element. The outer lobe is slightly wider than the inner, and directed posterolaterally. The posterior process bears compressed and basally fused denticles that are slightly smaller than those of the anterior process and cusp, and decrease in height toward the posterior tip.

Occurrence: Section GD (Table 1).

Material: 3 Pa elements.

Branmehla fissilis (BRANSON & MEHL, 1934a)

Plate 4, Figure 11

1934a Spathodus fissilis BRANSON & MEHL, p. 185, Pl. 17, Fig. 10.

Remarks: The Pa element of *Branmehla fissilis* is characterized by a moderately or strongly curved and slightly arched posterior blade that bears compressed and basally fused denticles. The upper margin of the denticles of the posterior process declines gradually to the posterior tip. There is no obvious cusp.

Occurrence: Section GD (Table 1).

Material: 2 Pa elements.

Branmehla gediki n. sp.

Plate 4, Figures 1-6

Etymology: Named in honor of İsmet Gedik in recognition of his contributions to the study of conodonts of Turkey.

Type locality and horizon: Grey, nodular limestone bed 10.3-10.8 m above the base of section GD, The Ayineburnu Member of the Tuzla Formation, Denizliköyü, Gebze, Kocaeli, nortwestern Turkey. Bed collected as sample GD7.

Holotype: The specimen illustrated on Plate 4, Figures 3-4.

Material: 44 Pa elements and 2 questionable specimens.

Range: At present, known from Lower *expansa* Zone and part of Middle *expansa* Zone.

Occurrence: Section GD (Table 1).

Diagnosis: Pa element overall straight or only slightly incurved posterior of cusp; posterior process with rudimentary denticles, about one-third length and one-half height of anterior process; basal cavity sub-circular, with an outer lobe about two times wider than inner lobe.

Description: Pa element overall straight or only slightly incurved posterior of cusp, with a prominent lateral expansion on midheight; lower profile straight or only slightly upflexed as from anterior end of cavity; anterior margin steep or reclined. Posterior process short and low, about one-third length and one-half or less height of anterior process, decreasing slightly in height to posterior tip, with rudimentary denticles or sometimes edentate; denticles 2-7, equal in height, but shorter than cusp and those on anterior process. Anterior process about three-fourths element length; lower and upper margins subparallel or in some specimens height of upper margin slightly increase anteriorly. Denticles on anterior process 4-14, subequal in size except for anteriormost one that may be markedly small on some specimens, laterally compressed, fused except for tips or may be fused for half their length. Cusp with a position above basal cavity apex, slightly larger than or subequal to denticles of anterior process. Basal cavity restricted to anterior part of posterior half of element, sub-circular in outline, may extend anteriorly and posteriorly as a tapering and shallowing furrow, and may possess a spear-shaped outline; lobes with different widths, and outer lobe about two times wider than inner lobe.

Remarks: The short and low posterior process with rudimentary denticles, and the subcircular basal cavity beneath the cusp are the most distinguishing characteristics of the Pa element of this species. The Pa element shows a close similarity to that of *Branmehla werneri* especially in lateral profile. However, they are distinguished in the shape of the basal cavity and in the features of the posterior process. The Pa element of *Branmehla werneri* has a narrow and elongate basal cavity beneath the prominent cusp and greatly reduced posterior process. In addition to the different shape of the basal cavity, there are generally no denticles posterior of the cusp in the Pa element of *Branmehla werneri.* However, the anterior process bears subequal denticles.

Compared with the Pa element of the present species, that of *Branmehla bohlenana* has a longer posterior process with well-developed denticles and a characteristic curvature, slightly curved inward and downward, about 1/3 element length. Furthermore, the outer lobe of the relatively short and wide, nearly elliptical basal cavity is wider than the inner lobe, and the long axis of the basal cavity lies obliquely to the axis of the unit. The Pa element of *Branmehla gediki* has a shorter posterior process with rudimentary denticles and a more circular basal cavity in contrast to that of the former.

Branmehla inornata (BRANSON & MEHL, 1934a)

Plate 4, Figures 22-24

1934a *Spathodus inornatus* BRANSON & MEHL, p. 185, Pl. 17, Fig. 23.

1959 *Branmehla inornata* (BRANSON & MEHL).- HASS, p. 381-382, Pl. 50, Fig. 3 (see synonymy).

1992 *Branmehla inornata* (BRANSON & MEHL).- OVER, p. 308, Fig. 6.31.

Remarks: The straight to slightly curved and unarched Pa element has laterally compressed and basally fused denticles of decreasing height anteriorly and posteriorly from the cusp. The cusp is only slightly higher and wider than the adjacent denticles. The asymmetrical basal cavity is positioned under the posterior third of the blade, expanding only slightly on the inner side, and wider on the outer side. In juvenile specimens the cusp is well developed and the posterior blade is reduced.

Occurrence: Sections GD and GB (Tables 1 & 2).

Material: 113 Pa elements.

Conclusions

The Tuzla Formation, which was originally described by Haas (1968), was divided by Kaya (1973) into three members: the Bostancı (limestone), Yörükali (chert), and Ayineburnu (chiefly nodular limestone). The sections studied, herein, belong to the Ayineburnu Member that is the equivalent of the "calcaires noduleux" of Abdüsselâmoğlu (1963) and the "Denizli beds" of Haas 1968). Some previous workers defined conodont faunas from beds equivalent to the Ayineburnu Member. The first conodont faunas were reported by Abdüsselâmoğlu (1963) from the villages of İçerenköy and Küçükyalı, 10 km east of the Bosphorus, İstanbul. This fauna includes *Palmatolepis minuta, Palmatolepis glabra distorta, Palmatolepis glabra prima, Palmatolepis perlobata schindewolfi, Palmatolapis marginifera marginifera* and *Palmatolepis gracilis,* and is of Famennian age. Furthermore, the latest Eifelian to Late Devonian conodonts, determined by Willi Ziegler, were obtained from the "Denizli beds", the equivalent of the Ayineburnu Member in Denizliköyü by Haas (1968). This fauna consists of *Polygnathus linguiformis, Polygnathus webbi, Polygnathus pseudofoliatus, Polygnathus xylus, Palmatolepis triangularis, Palmatolepis delicatula delicatula, Palmatolepis delicatula clarki, Palmatolepis quadrantinodosalobata* s.str., *Palmatolepis subperlobata,* and *Palmatolepis tenuipunctata*. Conodont faunas of the Upper *rhomboidea* and the Lower *marginifera* Zones are defined from the Büyükada section of the Ayineburnu Member (Çapkınoğlu 1997).

A total of 34 species and subspecies, one of which is a new species (*Branmehla gediki* n.sp.), are identified from two incomplete sections (GD and GB) of the Ayineburnu section in Denizliköyü, Gebze, Kocaeli, northwestern Turkey. This fauna, dominated by species of the palmatolepid-polygnathid biofacies (Sandberg 1976; Sandberg & Dreesen 1984), allows for correlation with the standard Late Devonian conodont zonation (Ziegler 1962; Ziegler & Sandberg 1984, 1990), and represents the Lower, Middle, and Upper *expansa* Zones.

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PLATE 1

All upper views unless otherwise indicated.

Figures 1-3. *Palmatolepis perlobata postera* ZIEGLER, 1960
1. GD18, x47, 2. GD24, x38, 3. GD24, x45.

Figure 4. *Palmatolepis gracilis expansa* SANDBERG and ZIEGLER, 1979
GD5, x45

Figure 5. *Palmatolepis perlobata schindewolfi* MÜLLER, 1956
GD8, x45.

Figures 6-7. *Palmatolepis rugosa ampla* MÜLLER, 1956
6. GD5, x36, 7. GD4, x36.

Figures 8-11. *Palmatolepis rugosa rugosa* BRANSON and MEHL, 1934.
8. GD24, x38, 9. GD24, x47, 10. GD13, x62 , 11. GD5, x40

Figures 12-14. *Palmatolepis gracilis sigmoidalis* ZIEGLER, 1962
12. Oblique-lateral view, GB17, x55, 13. Oblique-lateral view, GB3, x55, 14. Oblique-lateral view, GB19, x55.

Figures 15-18. *Palmatolepis gracilis gracilis* BRANSON and MEHL, 1934
15. GB2, x45, 16. GD8, x38, 17. GB2, x38, 18. GB2, x38.

Figure 19. *Peudopolygnathus micropunctatus* BISCHOFF and ZIEGLER, 1956
GB12, x45

Figures 20. *Palmatolepis gracilis manca* HELMS, 1963
GD4, x57

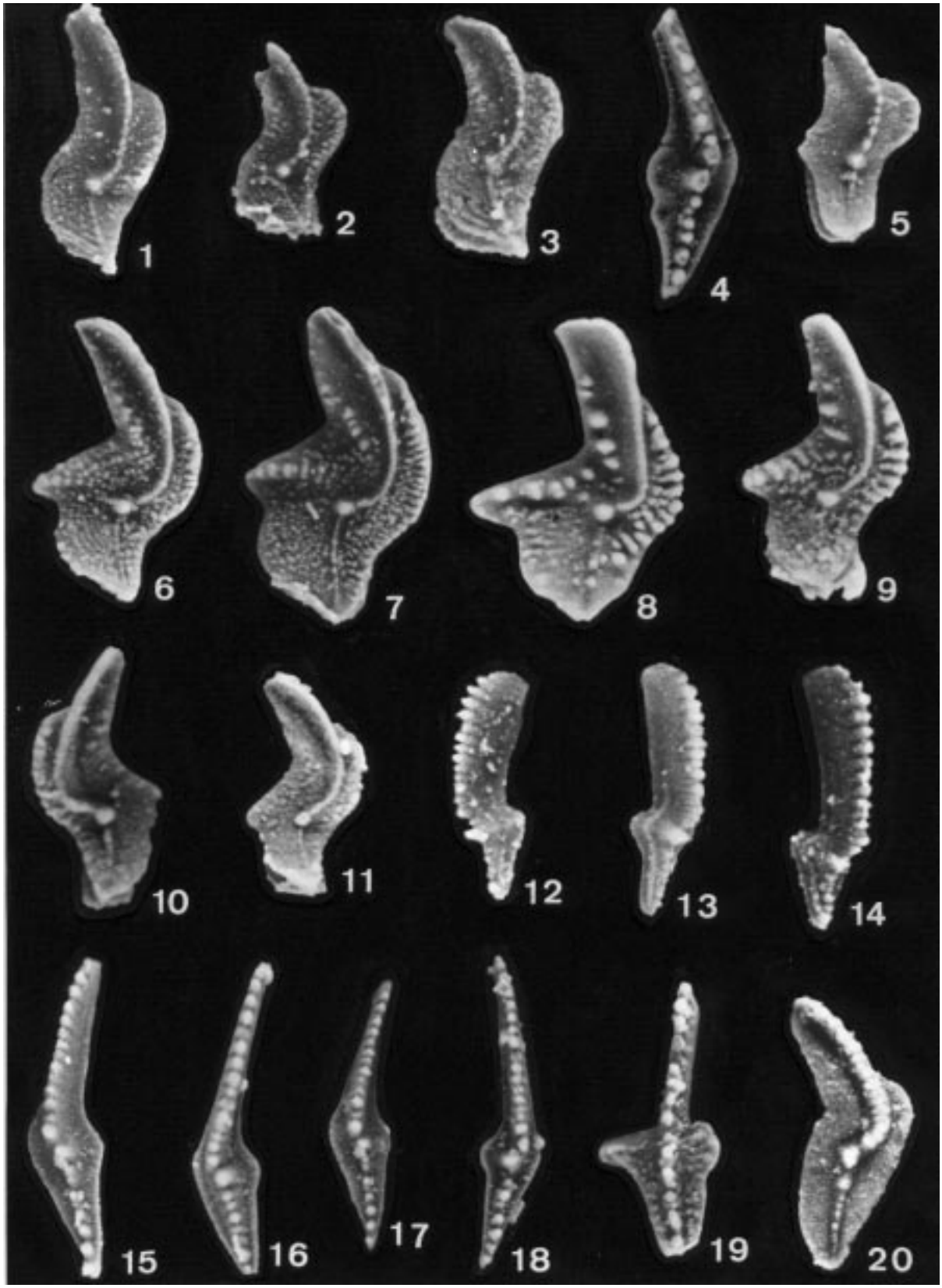
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PLATE 2

All upper views unless otherwise indicated.

Figures 1-3. *Polygnathus perplexus* THOMAS, 1949
1. GD15, x55, 2. GD20, x53, 3. GD15, x46.

Figures 4-5. *Pseudopolygnathus? kayseri* BISCHOFF and ZIEGLER, 1956
4. GD27, x40, 5. GD27, x60.

Figure 6. *Polygnathus rhabdotus* SCHÄFER, 1976
GD27, x47.

Figure 7. *Polygnathus znepolensis* SPASSOV, 1965
GD17, x55.

Figures 8-10. *Polygnathus styriacus* ZIEGLER, 1957
8. GD7, x35, 9. GD9, x35, 10. GD5, x40.

Figures 11-13. *Polygnathus* aff. *semicostatus* BRANSON and MEHL, 1934
11. GD9, x56, 12. GD9, x54, 13. GD13, x55.

Figure 14. *Polygnathus* cf. *subirregularis* SANDBERG and ZIEGLER, 1979
GD4, x55.

Figures 15-16. *Polygnathus communis communis* BRANSON and MEHL, 1934
15. GD29, x55, 16. GD27, x55.

Figures 17-21. *Polygnathus marginvolutus* GEDİK, 1969
17. GD15, x70, 18. GD11, x90, 19. GD13, x60, 20. GD13, x60, 21. GD15, x46.

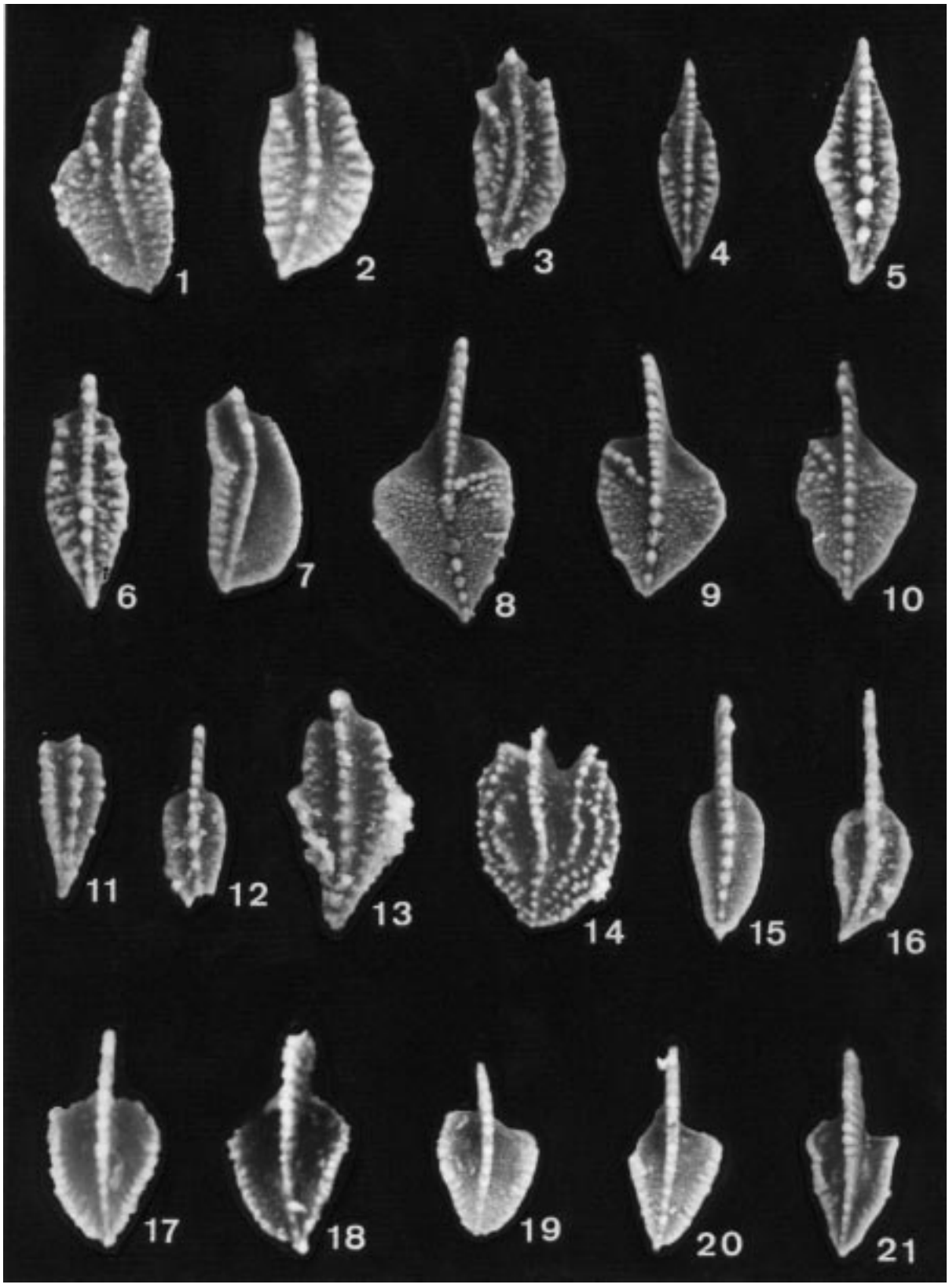
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PLATE 3

All upper views unless otherwise indicated.

Figures 1-4. *Bispathodus jugosus* (BRANSON and MEHL, 1934)
1. GD25, x45, 2. GD25, 39. GD25, x42, 2. GD25, x46.

Figure 5. *Bispathodus aculeatus aculeatus* (BRANSON and MEHL, 1934)
GB2, x55.

Figure 6. *Pseudopolygnathus* cf. *dentilineatus* BRANSON, 1934
GD24, x60

Figure 7. *Pseudopolygnathus marburgensis marburgensis* BISCHOFF and ZIEGLER, 1956
GB14, x55.

Figures 8-9. *Pseudopolygnathus marburgensis trigonicus* ZIEGLER, 1962
8. GB19, x45, 9. GB19, x36.

Figure 10. *Bispathodus bispathodus* ZIEGLER, SANDBERG, and AUSTIN, 1974
GB2, x55.

Figures 11-12. *Bispathodus* cf. *costatus* (BRANSON, 1934)
11. GB17, x57, 12. GB19, x57.

Figure 13-15. *Pseudopolygnathus micropunctatus* BISCHOFF and ZIEGLER, 1956
13. GD24, x55, 14. GD24, x56, 15. GD24, x55.

Figures 16, 18. *Bispathodus ultimus* (BISCHOFF, 1957)
16. GB17, x58, 18. GB17, x36.

Figures 17. *Bispathodus* cf. *spinulicostatus* (BRANSON, 1934)
GB19, x34.

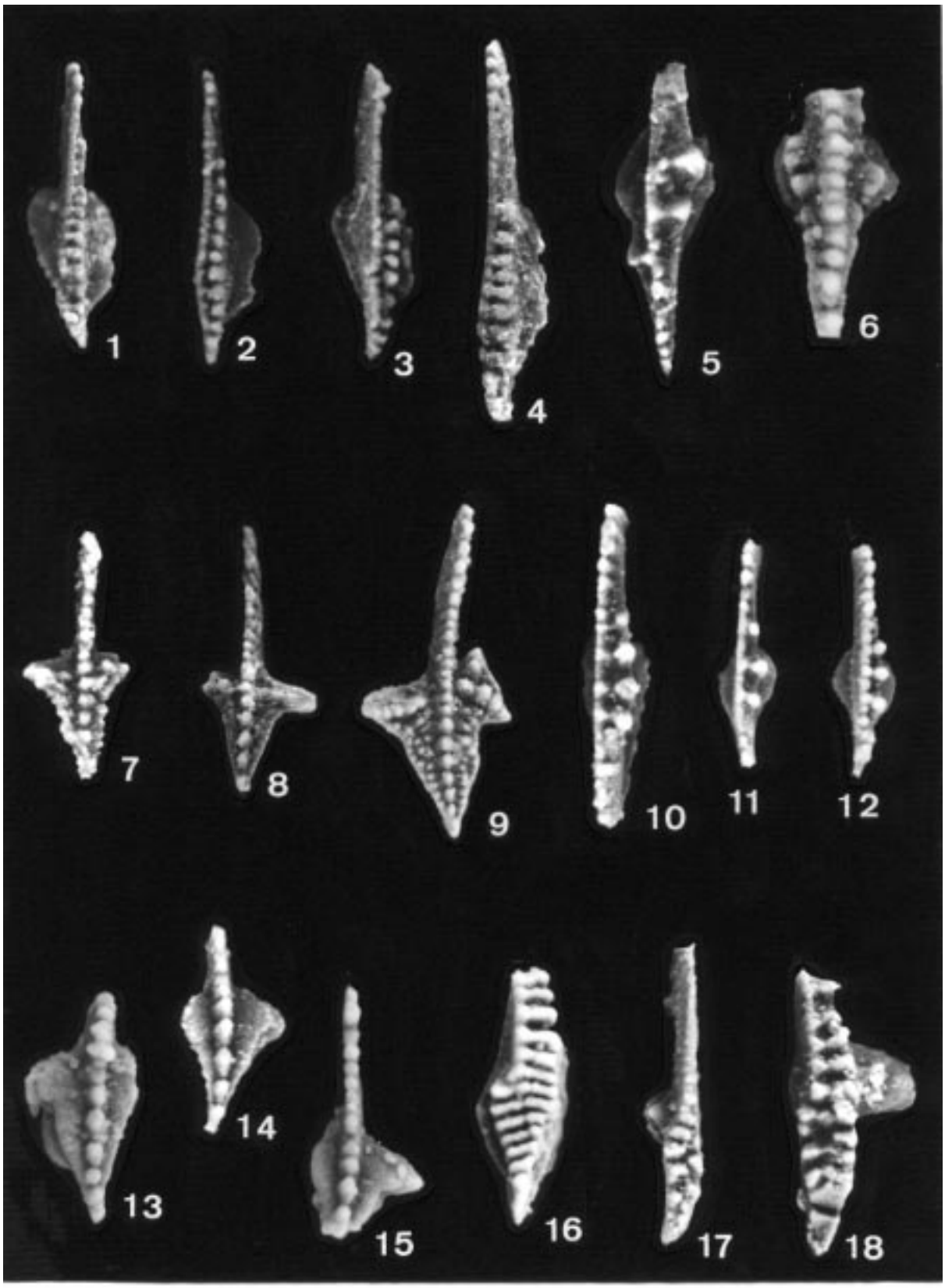
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PLATE 4

Figures 1-6. *Branmehla gediki* n.sp.

1-2. Inner-lateral and lower views of paratype,GD2, x46, 3-4. Inner-lateral and lower views of **holotype**, GD7, x55, 5. Inner-lateral view of paratype, GD9, x55, 6. Inner lateral view of paratype, GD14, x37.

Figures 7-10. *Branmehla bohlenana* (HELMS, 1959)

7-8. Outer-lateral and upper views, GD8, x37, 9-10. Inner-lateral and upper views, GD5, x47.

Figure 11. *Branmehla fissilis* (BRANSON and MEHL, 1934)

11. Inner-lateral view, GD20, x39.

Figure 12. *Bispathodus stabilis* (BRANSON and MEHL, 1934) Morphotype 1

Upper view, GD1, x48.

Figures 13-16. *Bispathodus stabilis* (BRANSON and MEHL, 1934) Morphotype 2

13-14. Lower and upper views, GD9, x55, 15-16. Lower and upper views, GD18, x37.

Figure 17-18. *Pseudopolygnathus* cf. *dentilineatus* BRANSON, 1934 (sensu SANDBERG and ZIEGLER, 1979)

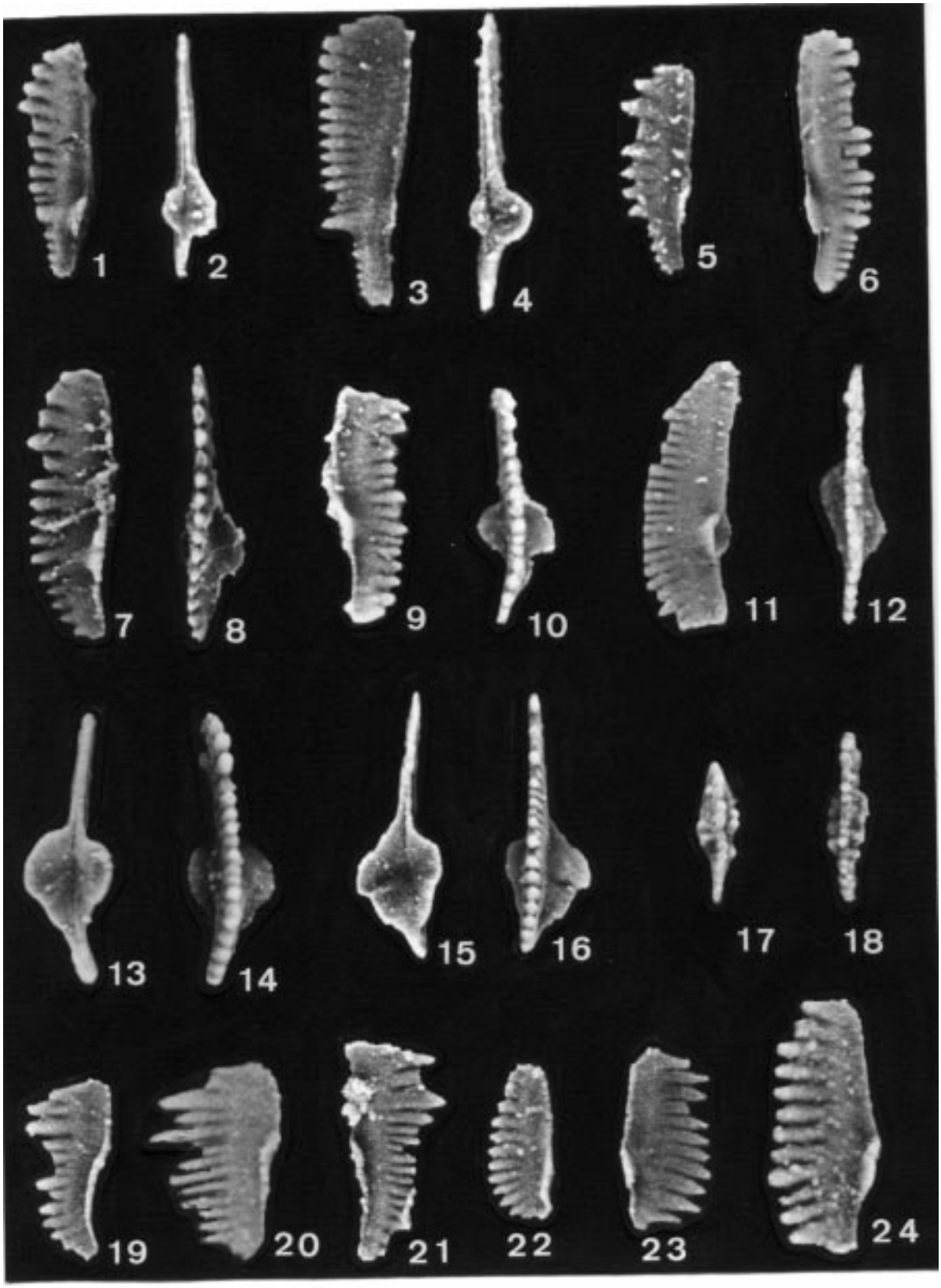
17. Upper view, GB4, x56, 18. Upper view, GB7, x56.

Figures 19-21. *Mehlina strigosa* (BRANSON and MEHL, 1934)

19. Lateral view, GD8, x48, 20. Lateral view, GD11, x70, 21. Lateral view, GD8, x36.

Figures 22-24. *Branmehla inornata* (BRANSON and MEHL, 1934)

22. Lateral view, GB19, x48, 23. Lateral view, GD18, x46, 24. Lateral view, GD25, x46.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