GEOLOGICA CARPATHICA, APRIL 2005, 56, 2, 113–122

Famennian conodonts from the Ayineburnu Formation of the Istanbul Zone (NW Turkey)

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(Manuscript received October 2, 2003; accepted in revised form June 16, 2004)

Abstract: Limestone samples from three incomplete stratigraphic sections of the Upper Devonian Ayineburnu Formation in the Denizliköyü area, Gebze, northwestern Turkey produced conodont faunas, which can be correlated with established Famennian conodont zones. The sections (D, DN and DB) consist mainly of interbedded planar to nodular limestones and dark shales, indicative of slope sedimentation. The sections D and DN define an interval extending from the Lower *marginifera* Zone into the *postera* Zone, and fill the gap between the former studied sections of the Ayineburnu Formation. The section DB contains the Lower and Middle *expansa* Zones.

Key words: Famennian, NW Turkey, Istanbul Zone, biostratigraphy, conodonts.

Introduction

The first conodont faunas from the Upper Devonian Ayineburnu Formation were reported by Abdüsselamoğlu (1963) and Haas (1968a,b). Initial conodont biostratigraphic studies and recognition of the established zonation scheme of Ziegler (1962, updated by Ziegler & Sandberg 1984, 1990) are more recent (Çapkınoğlu 1997, 2000, 2005). In the outcrop area in the Istanbul Zone of the Pontides (Fig. 1) no complete section of the Ayineburnu Formation has been described, therefore the conodont zones have been recognized from different sections (Fig. 2). The Famennian Upper *rhomboidea* and Lower *marginifera* Zones are recognized in the Büyükada (Istanbul) section (Çapkınoğlu 1997). The conodont faunas of the two incomplete sections sampled from the Denizliköyü area are assigned to the Lower, Middle, and Upper *expansa* Zones (Çapkınoğlu 2000). Conodonts of the Upper *rhenana* Zone (Frasnian) to the Uppermost *crepida* Zone (Famennian), excepting the Lower *triangularis* Zone, have been found in the Tuzla section in the Tuzla Peninsula, Istanbul (Çapkınoğlu 2005). Three new sections of the Ayineburnu Formation, documented herein, span an unsampled interval between the former sections that represent an interval extending from the Lower *marginifera* Zone into the Middle *expansa* Zone (Figs. 2 and 3).

Geologic setting and stratigraphy

General — the Istanbul Zone of the Pontides (Fig. 1) comprises a thick Ordovician–Early Carboniferous sedimentary sequence, deposited on a passive margin, changing to an active margin after the late Visean (Seymen 1995; Okay et al. 1996). This Paleozoic sequence, folded and possibly thrust-faulted during the Late Carboniferous–Permian Hercynian Orogeny, lies unconformably over a Precambrian crystalline basement, exposed in the Karadere area of Kastamonu (Arpat et al. 1978), and is unconformably overlain by Triassic or younger sedimentary rocks (Özdemir 1971; Gedik 1975).

The rocks of the Istanbul Zone show different tectonic and stratigraphic characteristics in the areas to the east and west of Kocaeli. On the basis of their different Paleozoic–Mesozoic history, Kozur & Göncüoğlu (1998) suggested that the Istanbul Zone belongs to two different terranes: the Istanbul Terrane consists of a Paleozoic–Mesozoic sequence around Istanbul-Gebze, and the Zonguldak Terrane of the Çamdağ, Zonguldak, Amasra and Safranbolu regions. Similar Paleozoic sequences are known only from the Balkan Peninsula and Central Europe. The stratigraphic similarity between the Istanbul Zone and the Moesian Platform has been noted, and the former is interpreted by some as a Hercynian fragment rifted from the southern margin of Laurasia during the Late Cretaceous (Okay et al. 1994, 1996). Kalvoda et al. (2003) also noted that there are close similarities between Neoproterozoic and Paleozoic strata(?) in the Brunovistulian Terrane of central Europe and the Istanbul Zone.

Ayineburnu Formation — the Denizliköyü area, some 75 km southeast of Istanbul and 20 km northeast of the town of Gebze, Kocaeli, is the major outcrop area of the Ayineburnu Formation, which forms the Upper Devonian part of the thick, Paleozoic sedimentary sequence of the Istanbul Zone (Fig. 1). The Ayineburnu consists of dark grey, nodular- to planar-bedded lime mudstones, interbedded with dark grey shale to marl partings or beds, and locally contains some chert nodules and interbeds. Sedimentological features indicate deposition in a slope environment (Önalan 1982, 1988; Seymen 1995), supported by an offshore palmatolepid-polygnathid conodont fauna (Çapkınoğlu 1997, 2000). Many sections are faulted and overturned or covered by soil as indicated in previous papers (Çapkınoğlu 1997, 2000, 2005), and therefore accurate estimates of the thickness of the Ayineburnu Formation are not possible.

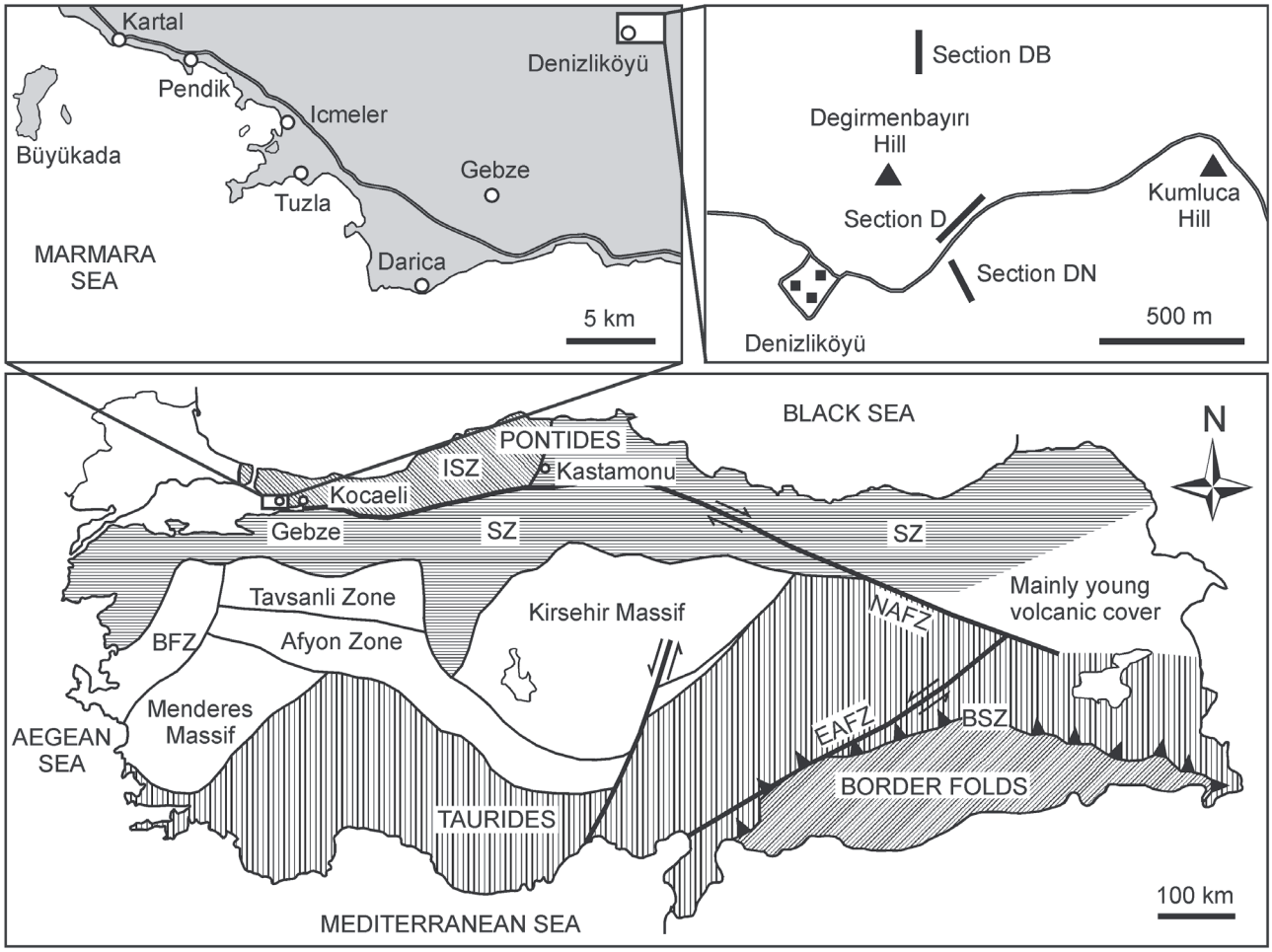


Fig. 1. Maps showing the tectonic units of Turkey (Okay et al. 1996), the location of the study area and the studied stratigraphic sections. **ISZ** — Istanbul Zone, **SZ** — Sakarya Zone, **BFZ** — Bornova Flysch Zone, **NAFZ** — North Anatolian Fault Zone, **EAFZ** — East Anatolian Fault Zone, **BSZ** — Bitlis Suture Zone.

The name Ayineburnu Formation is used, in this study, as equivalent of the Ayineburnu Member of previous papers (Kaya 1973; Önalan 1982, 1988; Çapkınoğlu 1997, 2000, 2005). Furthermore, it is synonymous with "nodular limestones" (Abdüsselamoğlu 1963), "Denizli beds" (Haas 1968a,b), and "Denizli formation" (Seymen 1995). The contacts with the underlying Yörükali Formation (the former Yörükali Member), and overlying Baltalimanı Formation are conformable (Kaya 1973; Önalan 1982). More detailed works related to the stratigraphy, sedimentology, and paleotectonic setting have been undertaken (Kaya 1973; Önalan 1982, 1988; Seymen 1995; Okay 1996).

Studied stratigraphic sections — three sections (D, DN and DB) of the Ayineburnu Formation in the Denizliköyü area were measured (Figs. 1 and 3). All the sections are incomplete, and have generally faulted lower and upper contacts. They are easily accessible on the north and west sides of Değirmenbayırı Hill. Section D, about 67 meters thick, is located on the north side of the Denizli highway and parallel to the road. Section DN is about 36 meters thick and nearly normal to the road. Section DB, 31.50 m thick, is on the north side of Değirmenbayırı Hill. Strata consist of limestone and interbedded shale or marl; sections D and DN are overturned.

Conodont biostratigraphy

Conodonts, abundant ostracodes, less trilobite and brachiopod shells, as well as rare fish teeth and scales were recovered by formic acid-leaching of limestone samples from three measured sections (D, DN, and DB) of the Ayineburnu Formation (Fig. 3). The materials consist of 93 samples, of which 45 produced the conodont faunas (Tables 1–3). Conodont yields were sparse, averaging less than ten specimens per kilogram of rock processed. Only eighteen samples yielded more than ten conodonts per kilogram of rock. The fossiliferous samples are poor in both diversity and population.

Section D — section D represents an interval ranging from the Lower *marginifera* Zone into the *postera* Zone (Fig. 3; Table 1). The co-occurrence of *Palmatolepis quadrantinodosa inflexoidea* and *Palmatolepis marginifera marginifera* in sample D22 defines the Lower *marginifera* Zone (see Ziegler &

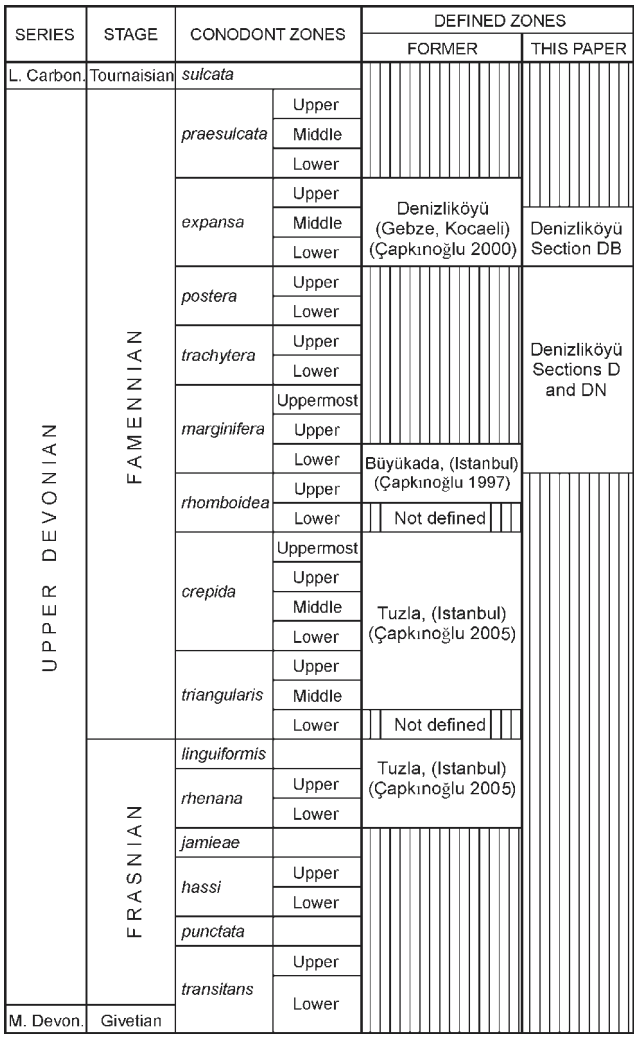


Fig. 2. The relative position and correlation of Upper Devonian strata in NW Turkey compared to stage boundaries and the conodont zonation of Ziegler (1962) most recently revised by Ziegler & Sandberg (1990).

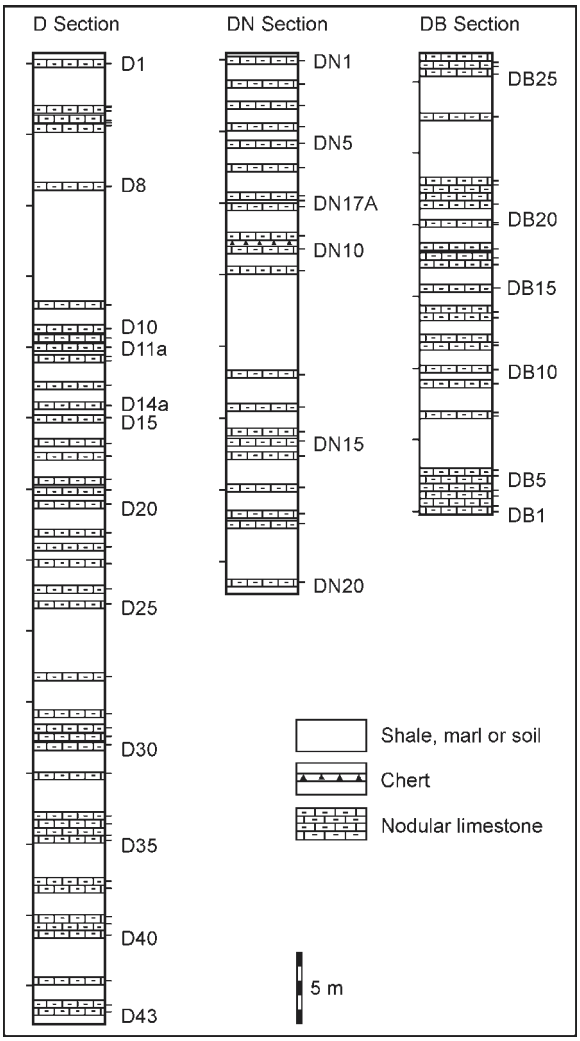


Fig. 3. Columnar sections of the studied sections of the Ayineburnu Formation at the Denizliköyü area showing lithology, and units sampled for conodonts.

Sandberg 1984, Fig. 2). The lower strata are questionably assigned to this zone, due to the absence of taxa characteristic of older zones. A badly broken specimen questionably referred to *Palmatolepis rugosa trachytera*, the index taxon of the *trachytera* Zone, was recovered in sample D8. Therefore, the samples D20 to D9 can be correlated with the Upper and Uppermost *marginifera* Zones. The overlying samples D8 and D7 represent the *trachytera* Zone. Sample D6a contains *Polygnathus obliquicostatus*, which first appears at the base of the *postera* Zone (Ziegler & Sandberg 1984, Fig. 3), and therefore it is within this zone. The overlying strata are assigned to the *postera* Zone due to the absence of defining taxa of any younger zones.

Section DN — section DN contains conodont faunas ranging from the Lower *marginifera* Zone or probably the Upper *rhomboidea* Zone into the *postera* Zone (Fig. 3; Table 2). The name-bearer taxon, *Palmatolepis marginifera marginifera*, was only found in samples DN14 and DN13 (Table 2). However, the lowest part of the section defines the Lower *marginifera* Zone, based on the occurrence of *Palmatolepis quadrantinodosa inflexoidea* in sample DN18 and *Palmatolepis quadrantinodosa inflexa* in sample DN14, both of which are mainly restricted to this zone (Ziegler & Sandberg 1984, Fig. 2), but it may extend into the older Upper *rhomboidea* Zone. The overlying samples DN13–DN9 do not contain zonally diagnostic conodonts, but they can be correlated to the Upper *marginifera* to *trachytera* Zones, on the basis of the first occurrence of *Polygnathus obliquicostatus* in sample DN7a. Due to the lowest occurrence of *Polygnathus obliquicostatus*, sample DN7a is within the *postera* Zone. Higher samples have also been assigned to this zone due to the lack of any taxa typical of younger zones.

Section DB — Conodont faunas of section DB are assigned to the Lower and Middle *expansa* Zones (Fig. 3; Table 3). *Palmatolepis gracilis expansa*, index species of the *expansa* Zone, occurs only in sample DB3. Sample DB23 is in the

Table 1: Distribution of conodonts in the D section of the Ayineburnu Formation in the Denizliköyü area, Gebze, Kocaeli, NW Turkey.

ZONE	Lower *marginifera*				Upper and Uppermost *marginifera*							*trachytera*		*post.*
SAMPLE	D41	D39	D24	D22	D20	D18	D15	D14a	D11	D10	D9	D8	D7	D6a
SAMPLE WEIGHT (kg)	0.60	0.50	1.35	1.00	1.00	1.10	0.70	0.45	0.70	0.90	1.00	0.55	0.70	0.50
Palmatolepis glabra pectinata	1						1			3	6			
Mehlina strigosa		1	1						2		2		2	
Palmatolepis glabra prima			1	1			2				4			
Palmatolepis minuta minuta			1	3			2					1	2	
Palmatolepis gracilis gracilis				1							3			
Palmatolepis marginifera marginifera				1			1			1	4			
Palmatolepis quadrantinodosa inflexoidea				1										
Palmatolepis glabra lepta					1							1		
Polygnathus glaber glaber						1								
Palmatolepis glabra acuta							1	1						
Polygnathus subnormalis							3				2			
Palmatolepis glabra distorta											1			
Palmatolepis gracilis sigmoidalis											1			
Palmatolepis perlobata schindewolfi											1	1	4	1
Palmatolepis rugosa trachytera												1?		
Polygnathus communis communis													1	
Polygnathus obliquicostatus														1

Table 2: Distribution of conodonts in the DN section of the Ayineburnu Formation in the Denizliköyü area, Gebze, Kocaeli, NW Turkey.

ZONE	U. *rhomboidea?* - Lower *marginifera*			Upper *marginifera-trachytera*					*postera*					
SAMPLE	DN18	DN15	DN14	DN13	DN12	DN11	DN10	DN9	DN7a	DN7	DN5	DN4	DN3	DN2
SAMPLE WEIGHT (kg)	0.70	0.50	0.70	0.70	0.40	0.40	0.45	0.50	0.70	0.60	0.90	0.80	0.75	0.50
Palmatolepis minuta minuta	2													
Palmatolepis perlobata schindewolfi	1			1										3
Palmatolepis quadrantinodosa inflexoidea	1													
Palmatolepis rhomboidea	1													
Palmatolepis glabra acuta		1?												
Palmatolepis glabra lepta					1									
Palmatolepis glabra pectinata			6	4										
Palmatolepis glabra prima			8	1										
Palmatolepis gracilis gracilis			12			1							2	1?
Palmatolepis marginifera marginifera			7	1										
Palmatolepis quadrantinodosa inflexa			4											
Polygnathus glaber glaber			1											
Bispathodus stabilis			1								6	2		
Branmehla gediki			1								2			6
Mehlina strigosa			3				2				4		1	3
Palmatolepis rugosa cf. *ampla*				2										
Polygnathus diversus					1									
Polygnathus communis communis						1								
Polygnathus rhabdotus								2						
Polygnathus obliquicostatus									1	1				
Polygnathus styriacus											6	2	1	6
Branmehla inornata											2		1	1
Branmehla bohlenana												1	2	
Palmatolepis rugosa ampla													4	
Palmatolepis gracilis sigmoidalis														3
Polygnathus marginvolutus														4

Lower *expansa* Zone according to the occurrence of *Polygnathus styriacus*, which is last known at the end of this zone (Ziegler & Sandberg 1984, Fig. 2). Furthermore, the next younger sample DB24 records the first occurrence of *Bispathodus aculeatus*, which defines the base of the Middle *expansa* Zone. This indicates that the samples DB3–DB23 belong to the Lower *expansa* Zone. The overlying samples are assigned to the Middle *expansa* Zone due to the absence of diagnostic taxa of the younger zones.

Systematic paleontology

The familial classification proposed by Sweet (1988) is followed here. Conodont faunas belong to the families Icriodontidae (1 taxon), Palmatolepidae (19 taxa), Polygnathidae (11 taxa), and Spathognathodontidae (5 taxa), Unknown (3 taxa). Because most of the forms encountered in the study have been documented in previous papers, they are not formally described but are recorded on the distribution tables (Tables 1–

3) and illustrated on plates (Figs. 4–5). All the samples are housed in the Department of Geological Engineering, Karadeniz Technical University, Trabzon.

Family: **Palmatolepidae** Sweet, 1988
Genus: *Palmatolepis* Ulrich et Bassler, 1926
Type species: *Palmatolepis perlobata* Ulrich et Bassler, 1926

Palmatolepis rugosa cf. *ampla* Müller, 1956
Fig. 4.9

1960 *Palmatolepis rugosa ampla* Müller, Ziegler in Kronberg et al., pl. 1, Figs. 3–4 (only)
1962 *Palmatolepis rugosa ampla* Ziegler, pl. 8, Fig. 6 (only)
1967 *Palmatolepis rugosa ampla* Wolska, pl. 11, Fig. 10 (only)

Remarks: The present Pa elements referred to this subspecies closely resemble those of *Palmatolepis rugosa ampla* but differ in the arrangement of nodes in the anterior part of the outer platform. *Palmatolepis rugosa ampla* (Fig. 4.7–4.8) bears a single row of large nodes in the anterior part of its outer platform, which forms a posterioward-directed acute angle with the blade, whereas the older form *Palmatolepis rugosa* cf. *ampla* has many random nodes in the same position.

Palmatolepis rugosa trachytera Ziegler, 1960

1960 *Palmatolepis rugosa trachytera* Ziegler in Kronberg et al., p. 38, pl. 1, Fig. 6, pl. 2, Figs. 1–9
1984 *Palmatolepis rugosa trachytera* Ziegler et Sandberg, p. 187–188, pl. 1, Figs. 1–5, 12 (see synonymy)

Remarks: One incomplete Pa element not illustrated here has questionably been assigned to this taxon on the basis of the posterior part forming a nearly right angle with the carina.

Family: **Polygnathidae** Bassler, 1925
Genus: *Polygnathus* Hinde, 1879
Type species: *Polygnathus dubius* Hinde, 1879

Polygnathus diversus Helms, 1959
Fig. 5.7

1959 *Polygnathus diversa* Helms, p. 650–651, pl. 5, Figs. 5–8; text-Fig. 2
1961 *Polygnathus diversa* Helms, p. 681, pl. 1, Figs. 4–6; pl. 2, Figs. 2–5; text-Fig. 2a,c
1966 *Polygnathus diversa* Glenister et Klapper, p. 828, pl. 94, Fig. 7
1967 *Polygnathus diversa* Wolska, p. 412, pl. 16, Figs. 6, 7
1985 *Polygnathus diversus* Helms. Olivieri, pl. 7, Figs. 2–5
1990 *Polygnathus diversus* Perri et Spalletta, p. 64–65, pl. 4, Fig. 8a,b

Remarks: The free blade offset from the carina and the platform ornament consisting of need-like denticles confined mainly to the platform margins bordering the shallow adcarinal troughs are the most important features defining the Pa element of this species. The anterior outer margin commonly extends farther anteriorly than the inner margin, giving the platform an asymmetrical appearance. The inner margin terminates posterior of the offset point of the blade, and the outer margin anterior of that position. The free blade is slightly

Table 3: Distribution of conodonts in the DB section of the Ayineburnu Formation in the Denizliköyü area, Gebze, Kocaeli, NW Turkey.

ZONE	**Lower *expansa***													**Middle *expansa***			
SAMPLE	**DB3**	**DB5**	**DB6**	**DB8**	**DB12**	**DB13**	**DB14**	**DB17**	**DB18**	**DB19**	**DB21**	**DB22**	**DB23**	**DB24**	**DB25**	**DB26**	**DB27**
SAMPLE WEIGHT (Kg)	**1.15**	**0.90**	**0.70**	**1.00**	**0.60**	**0.80**	**1.00**	**0.50**	**0.85**	**1.00**	**1.15**	**0.80**	**0.85**	**1.00**	**0.65**	**0.70**	**0.80**
Palmatolepis gracilis expansa	1																
Palmatolepis gracilis gracilis	1	2		1	1	1	6			1	2	1	6	2			
Palmatolepis gracilis sigmoidalis	3		1			5	1				3	7	3	4	2		1
Palmatolepis perlobata schindewolfi	2		2	3	3			1		2	1	4	4				
Polygnathus perplexus	1																
Polygnathus rhabdotus	2		1	6													
Bispathodus stabilis Morphotype1	2						1	2			3	2	1	1			
Mehlina strigosa	1	1			3	2	1			7	1	14	13	3			
Polygnathus obliquicostatus		2															
Icriodus alternatus alternatus		1															
Polygnathus extralobatus			1										1				
Polygnathus styriacus			1		5	3	5		1	1	4	6	8				
Polygnathus granulosus				1													
Branmehla gediki					12	13	5				2	3	7			1	
Branmehla bohlenana						1					2						
Branmehla inornata						7	3					2	14	4			
Palmatolepis rugosa ampla							3			1	3	8	1				
Palmatolepis gracilis manca										1							
Polygnathus cf. *irregularis*												1	1				
Polygnathus marginvolutus												2					
Polygnathus communis communis														17			
Pseudopolygnathus cf. *dentilineatus*														2			
Bispathodus aculeatus plumulus														2			
Bispathodus jugosus														6			



Fig. 4. Famennian conodonts from the Ayineburnu Formation of the Istanbul Zone, NW Turkey. All figures are upper views of Pa elements unless otherwise stated. **1** — *Palmatolepis glabra acuta* Helms, 1963; Sample D14a. **2** — *Palmatolepis glabra pectinata* Ziegler, 1962; Sample D9. **3–4** — *Palmatolepis glabra prima* Ziegler et Huddle, 1969; 3 — Sample D15, 4 — Sample D24. **5–6** — *Palmatolepis glabra lepta* Ziegler et Huddle, 1969; 5 — Sample D8, 6 — Sample DN12. **7–8** — *Palmatolepis rugosa ampla* Müller, 1956; 7 — Sample DB22, 8 — Sample DN13. **9** — *Palmatolepis rugosa* cf. *ampla* Müller, 1956; Sample DN3. **10** — *Palmatolepis minuta minuta* Branson et Mehl, 1934a; Sample D22. **11–12** — *Palmatolepis gracilis gracilis* Branson et Mehl, 1934a; 11 — Sample DB5, 12 — Sample DB23. **13–14** — *Palmatolepis gracilis sigmoidalis* Ziegler, 1962; 13 — Oblique-lateral view, sample DN2, 14 — Oblique-lateral view, sample DB27. **15–18** — *Palmatolepis perlobata schindewolfi* Müller, 1956; 15 — Sample D8, 16 — Sample D9, 17 — Sample DB6, 18 — Sample DB17. **19** — *Palmatolepis gracilis expansa* Sandberg et Ziegler, 1979; DB3. **20–22** — *Palmatolepis quadrantinodosa inflexa* Müller, 1956; 20 — Sample D22, 21 — Sample DN14, 22 — Sample DN14. **23** — *Palmatolepis gracilis manca* Helms, 1963; Sample DB19. **24** — *Palmatolepis quadrantinodosa inflexoidea* Ziegler, 1962; Sample DN18. **25–27** — *Palmatolepis marginifera marginifera* Helms, 1959; 25 — Sample D9, 26 — Sample DN14, 27 — Sample DN14. **28** — *Palmatolepis rhomboidea* Sannemann, 1955; Sample DN18. All scale bars = 0.1 mm.

shorter than the platform. The basal cavity occurs just posterior of the anterior tip of the platform.

Polygnathus extralobatus Schäfer, 1976
Fig. 5.1

1976 *Polygnathus extralobatus* Schäfer, p. 143–144, pl. 1, Figs. 16–17, 23–26, text-Fig. 2
1979 *Polygnathus extralobatus* Sandberg et Ziegler, p. 188, pl. 5, Fig. 11 (see synonymy)
1991 *Polygnathus extralobatus* Perri et Spalletta, p. 70–71, pl. 5, Figs. 4–6

Remarks: The inner platform of the Pa element bears oblique transverse ridges, which form a posteriorward-directed acute angle with the carina as in *Polygnathus obliquicostatus*, but its broadly expanded posterior platform distinguishes this species from the latter. In addition, the outer platform bears curved transverse ridges, which are set vertically to the carina posteriorly and diagonally to it anteriorly. Posterior platform has transverse ridges crossing the entire platform. Anterior platform is conspicuously constricted with a rostral development.

Polygnathus granulosus Branson et Mehl, 1934a
Fig. 5.14

1934a *Polygnathus granulosa* Branson et Mehl, p. 246, pl. 20, Figs. 21, 23
1973 *Polygnathus granulosus* Branson et Mehl — Ziegler in Ziegler (Ed.), p. 361–362, *Polygnathus* — pl. 3, Figs. 6–7 (see synonymy)
1990 *Polygnathus granulosus* Perri et Spalletta, p. 65, pl. 5, Figs. 4a–5b

Remarks: The Pa element represented by a single specimen in the collection has a lanceolate platform ornamented with indistinct rows of nodes oblique to the carina with larger nodes anteriorly. The anterior smooth part of the platform is steeply deflected downward. The free blade is approximately one-third of the unit length.

Polygnathus marginvolutus Gedik, 1969
Fig. 5.22

1969 *Polygnathus marginvolutus* Gedik, p. 237, pl. 5, Figs. 2–8
1974 *Polygnathus marginvolutus* Gedik, p. 20, pl. 5, Figs. 2–8
1991 *Polygnathus marginvolutus* Perri et Spalletta, p. 71, pl. 6, Figs. 1–2 (see synonymy)

Remarks: Pa element possesses a triangular platform with the troughs narrowing and shallowing posteriorly, and widening and deepening anteriorly. Upturned platform margins bear nodes or short transverse ridges. The anterior two-thirds of the platform is sharply deflected downward. The carina is slightly curved. The free blade is about one-half to one-third of the platform length. The basal pit set in the keel is generally too small to recognize.

Polygnathus obliquicostatus Ziegler, 1962
Fig. 5.2–5.3

1962 *Polygnathus obliquicostatus* Ziegler, p. 92–93, pl. 11, Figs. 8–12
1975 *Polygnathus obliquicostatus* Ziegler in Ziegler (Ed.), p. 311–312, *Polygnathus* — pl. 5, Fig. 5 (see synonymy)

Remarks: Pa elements assigned to *Polygnathus obliquicostatus* have a platform with the prominent rostrum, and with transverse ridges oblique to the carina on the inner platform and perpendicular to it on the outer side, characteristic of this species. It is distinguished from *Polygnathus extralobatus*, with a broadly expanded outer platform and a more curved carina, by absence of the outer expansion; from *Polygnathus semicostatus* by having transverse ridges oblique to the carina on the inner platform and a prominent rostrum. Pa elements of *Polygnathus semicostatus* possess transverse ridges perpendicular to the carina on the inner platform, and a well-developed platform tongue.

Polygnathus rhabdotus Schäfer, 1976
Fig. 5.5–5.6

1961 *Polygnathus* n.sp. A. Helms, p. 697, pl. 4, Figs. 23, 28, 29
1976 *Polygnathus rhabdotus* Schäfer, p.146, pl. 1, Figs. 18–22

Remarks: A short free blade with about one-third of the platform length, and a platform ornament consisting of strong transverse ridges anteriorly and changing to transversely aligned nodes on posterior two-thirds define the Pa element of *Polygnathus rhabdotus*. The platform ornament of the juvenile specimens consists of nodes restricted to the platform margins. Except for the upper platform ornament, Pa element is closely similar to that of *Polygnathus pennatulus*, but the platform, in the latter, has well-developed, unbroken transverse ridges.

Polygnathus cf. *irregularis* (Thomas, 1949)
Fig. 5.9–5.10

Description: Pa element has a rhomb-shaped platform with the rostral ridges and troughs confined to the anterior half of the platform. The upper surface is ornamented with rows of nodes diagonal to the carina anteriorly, and random nodes to irregular rows of nodes posteriorly. The platform is asymmetrical and the widest in the midlength. The right side is broadly expanded with nearly triangular outline, and the left side a convex curve. The carina is straight to deflected laterally at midlength, and may or may not extend to the posterior tip. The short free blade is about one-fifth of the unit length.

Remarks: Pa element resembles those of *Polygnathus irregularis* and *Polygnathus subirregularis*, but differs by its widely expanded platform with a lobe-like development on the right side. One of the illustrated samples (Fig. 5.10) has a carina development with lateral deflection at midlength that is similar to *Polygnathus subirregularis*, but Pa element of the latter has a narrower and more elongate platform.

Family: **Spathognathodontidae** Hass, 1959
Genus: *Bispathodus* Müller, 1962
Type species: *Spathodus spinulicostatus* Branson, 1934

Bispathodus aculeatus plumulus (Rhodes, Austin et Druce, 1969)
Fig. 5.16

1975 *Bispathodus aculeatus plumulus* (Rhodes, Austin et Druce,

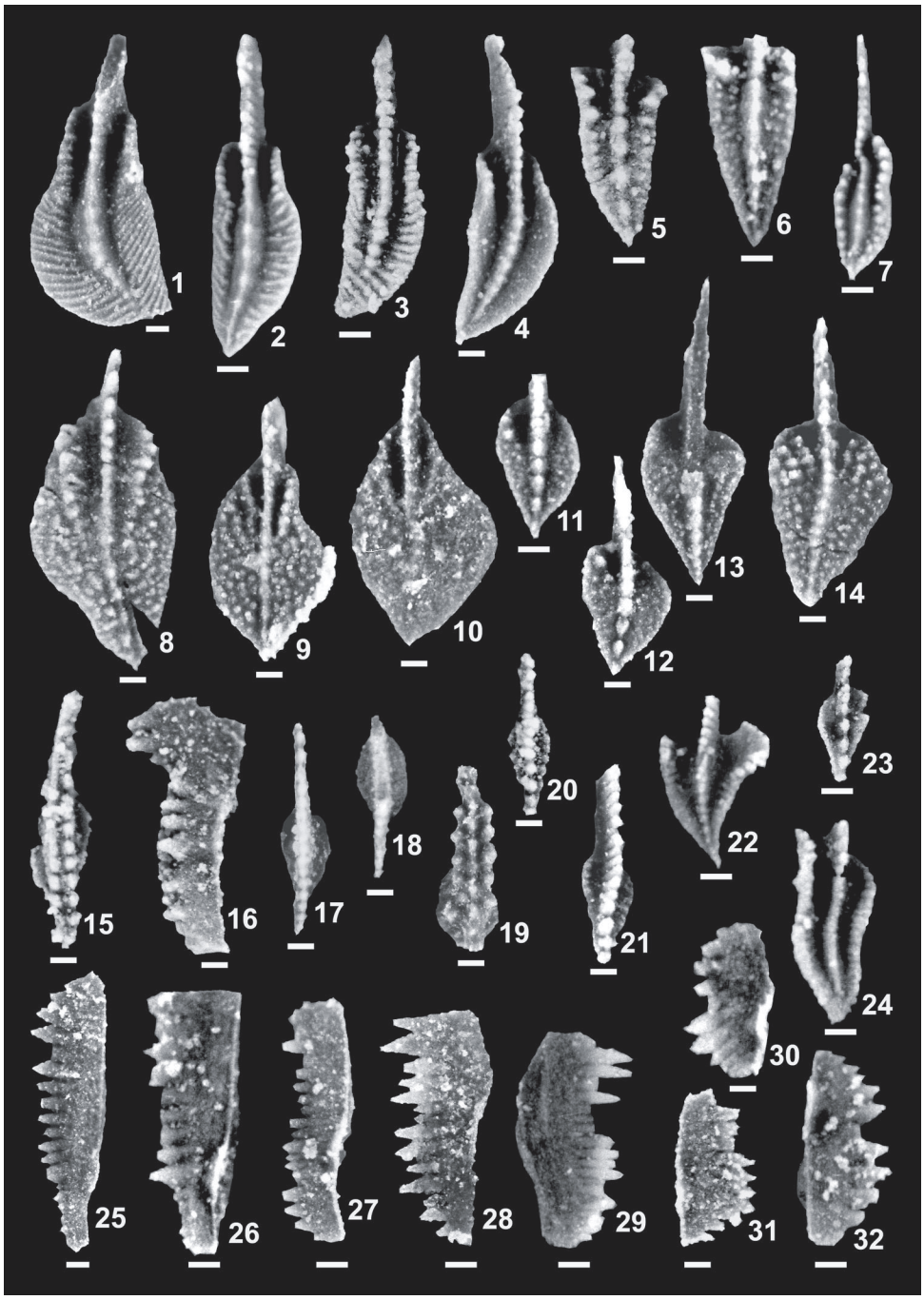


Fig. 5. Famennian conodonts from the Ayineburnu Formation of the Istanbul Zone, NW Turkey. All figures are upper views of Pa elements unless otherwise stated. **1** — *Polygnathus extralobatus* Schäfer, 1976; Sample DB23. **2–3** — *Polygnathus obliquicostatus* Ziegler, 1962; 2 — Sample DN7, 3 — Sample DN5. **4** — *Polygnathus communis communis* Branson et Mehl, 1934b; DB24. **5–6** — *Polygnathus rhabdotus* Schäfer, 1976; 5 — Sample DB3, 6 — Sample DN9. **7** — *Polygnathus diversus* Helms, 1959; Sample DN12. **8** — *Polygnathus perplexus* Thomas, 1949; Sample DB3. **9–10** — *Polygnathus* cf. *irregularis* (Thomas, 1949); 9 — Sample DB23, 44, 10 — Sample DB22. **11–13** — *Polygnathus styriacus* Ziegler, 1957; 11 — Sample DN5, 12 — Sample DB21, 13 — Sample DB6. **14** — *Polygnathus granulosus* Branson et Mehl, 1934a; 14 — Sample DB8. **15** — *Bispathodus jugosus* (Branson et Mehl, 1934a); Sample DB24. **16** — *Bispathodus aculeatus plumulus* (Rhodes, Austin et Druce, 1969); Lateral view, sample DB24. **17–18** — *Bispathodus stabilis* (Branson et Mehl, 1934a); 17 — Sample DB21, 18 — Sample DN4. **19** — *Icriodus alternatus alternatus* Branson et Mehl, 1934a; Sample DB5. **20–21** — *Pseudopolygnathus* cf. *dentilineatus* Branson, 1934; 20 — Sample DB24, 21 — Sample DB4. **22** — *Polygnathus marginvolutus* Gedik, 1969; Sample DN2. **23** — *Polygnathus glaber glaber* Ulrich et Bassler, 1926; Sample DN14. **24** — *Polygnathus subnormalis* Vorontzova et Kuzmin, 1984; Sample D15. **25–26** — *Branmehla gediki* Çapkınoğlu, 2000; 25 — Lateral view, sample DB21, 26 — Inner-lateral view, sample DN14. **27** — *Branmehla bohlenana* (Helms, 1959); Lateral view, Sample D21. **28–29** — *Mehlina strigosa* (Branson et Mehl, 1934a); 28 — Lateral view, Sample DB24, 29 — Lateral view, Sample DN3. **30–32** — *Branmehla inornata* (Branson et Mehl, 1934a); 30 — Lateral view, Sample DN5, 31 — Lateral view, Sample DB24, 32 — Lateral view, Sample DN5. All scale bars = 0.1 mm.

1969) — Ziegler in Ziegler (Ed.), p. 29–30, *Bispathodus* — pl. 1, Figs. 8–10 (see synonymy)

Remarks: The present Pa elements possess a plume-like anterior blade with reclined (recurved) denticles increasing the heights posteriorly, the distinctive characteristic of *Bispathodus aculeatus plumulus*. Three to four discrete denticles occur on the right side of the blade.

Bispathodus jugosus (Branson et Mehl, 1934a)
Fig. 5.15

1934a *Spathodus jugosus* Branson et Mehl, p. 190-191, pl. 17, Figs. 19, 22(?)
1974 *Bispathodus jugosus* (Branson et Mehl) — Ziegler, Sandberg et Austin, p. 103, pl. 1, Figs. 3, 4; pl. 3, Figs. 19, 23, 26.

Remarks: The Pa elements have a trough or a few germ denticles inserted between the main and lateral row denticles at the posterior tip of the blade, characteristic of this species.

Family: **Unknown** Sweet, 1988
Genus: *Branmehla* Hass, 1959
Type species: *Spathodus inornatus* Branson et Mehl, 1934a

Branmehla gediki Çapkınoğlu, 2000
Fig. 5.25–5.26

1991 *Branmehla bohlenana* Helms, Perri et Spalletta, p. 58,60, pl. 3, Fig. 1a,c;
1998 *Branmehla bohlenana* Perri et Spalletta, p. 164-165, pl. 1.4.1, Fig. 4a,c.
2000 *Branmehla gediki* Çapkınoğlu, p. 101, pl. 4, Figs. 1–6.

Remarks: Distinctive characteristics of the Pa element of *Branmehla gediki* are the short and low posterior process with markedly smaller denticles than the anterior process, and the subcircular basal cavity beneath the cusp. The basal cavity extends anteriorly and posteriorly as a slit-like groove.

Although the Pa element shows a close similarity to that of both *Branmehla werneri* and *Branmehla bohlenana* they are distinguished in the shape of the basal cavity and in the characteristics of the posterior process (see Çapkınoğlu 2000). *Branmehla werneri* has a narrow and elongate basal cavity beneath a low, wide cusp and greatly reduced posterior process, and *Branmehla bohlenana,* has an elliptical basal cavity, the long axis of which lies obliquely to the axis of the blade. The Pa elements of *Branmehla bohlenana* commonly have a posterior process with a gradually decreasing height posteriorward of the cusp and therefore, a convex upper profile. In the Pa element of *Branmehla gediki*, the posterior process abruptly decreases to about half-height of the anterior process just after the cusp, and has an even upper profile. Furthermore it has a more prominent cusp than *Branmehla bohlenana*.

Branmehla gediki was initially described from the *expansa* Zone (Çapkınoğlu 2000), but occurs from the Lower *marginifera* Zone into the Middle *expansa* Zone. Some specimens, which have been referred to *Branmehla bohlenana,* have been illustrated from the Lower *expansa* and Upper *postera* Zones of the Carnic Alps, Italy (Perri & Spalletta 1991, 1998).

Conclusions

Upper Devonian conodont zones extending from the Lower *rhenana* Zone to the Upper *expansa* Zone, except for the Lower *triangularis* and Lower *rhomboidea* Zones, have been recognized from the outcrop sections in different areas of the Upper Devonian Ayineburnu Formation in the Istanbul Zone, NW Turkey (Fig. 2). The Tuzla section, measured in strata exposed on the Tuzla Peninsula, contains the Frasnian-Famennian (F/F) boundary (Çapkınoğlu 2005). The Lower *triangularis* Zone, the base of which corresponds to the F/F boundary, is poorly defined or absent in the Tuzla section, which is now covered. The Lower *rhomboidea* Zone and the Lower through Upper *praesulcata* Zones, the youngest conodont zones of the Upper Devonian, the upper boundary of which corresponds to the Devonian-Carboniferous (D/C) boundary, are also unrecognized due to the sampling scheme. The D/C boundary is probably in bedded cherts and siliceous shales bearing phosphatic nodules of the Baltalimanı Formation overlying the Ayineburnu Formation in the Denizliköyü area. The sections studied here span an interval extending from the Lower *marginifera* Zone into the Middle *expansa* Zone, and document the unsampled interval between sections studied earlier (Fig. 2).

Additionally, the range of *Branmehla gediki*, previously known from the Lower and Middle *expansa* Zones (Çapkınoğlu 2000), is extended from the Middle *expansa* Zone downward into the Lower *marginifera* Zone.

Acknowledgments: This research was partly supported by Karadeniz Technical University (Trabzon, Turkey), Science Foundation (Project No: 21.112.005.6). I would like to thank D. Jeffrey Over of SUNY Geneseo, for critically reviewing the manuscript, and İsmet Gedik of KTÜ Department of Geological Engineering, for his criticism and advice. I also thank M.C. Perri, C. Girard and J. Hladil for reviewing the submitted manuscript and making valuable suggestions.

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