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Upper Devonian (Upper Frasnian–Lower Famennian) conodont biostratigraphy of the Ayineburnu Formation (Istanbul Zone, NW Turkey)

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Abstract: Conodont faunas, which generally represent the pelagic palmatolepid-polygnathid or palmatolepid biofacies and correlate well with the standard Upper Devonian conodont zonation, were obtained from an incomplete stratigraphic section of the Ayineburnu Formation, Istanbul Zone, Turkey. Three of the upper Frasnian standard conodont zones extending from the Lower *rhenana* Zone into the *linguiformis* Zone, and six of the lower Famennian standard conodont zones extending from the Middle *triangularis* Zone into the Uppermost *crepida* Zone have been recognized with these conodont faunas. Zonal indices for the Lower *triangularis* Zone and the Frasnian/Famennian (F/F) boundary are not present. Strata assigned to the *linguiformis* Zone are overlain by a one meter unsampled interval. The next sample represents the Middle *triangularis* Zone, the conodont faunas of which are densely covered by matrix, suggesting a reworking. Also, the presence of the Lower and Middle *crepida* Zones is based on the recognition of only the lower and upper limits, respectively. The boundary between these zones could not be determined due to the absence of the zonally diagnostic taxa.

Key words: Upper Devonian, Frasnian, Famennian, Turkey, biostratigraphy, conodonts.

Introduction

The Pontides, one of the main tectonic units of Turkey, comprise the Strandja, Sakarya and Istanbul Zones with different stratigraphic and tectonic developments (Fig. 1). The Turkish part of the Strandja Zone consists of a basement of felsic gneiss and migmatite, intruded by Hercynian granitic plutons, which is unconformably overlain by the Triassic continental to shallow-marine clastics and carbonates. The basement of the Sakarya Zone comprises two tectonic assemblages that were juxtaposed during the Triassic: a lower assemblage of Paleozoic granitic and metamorphic rocks, and an upper assemblage of accretion–subduction units of the Paleo-Tethys, termed the Karakaya Complex. A Mesozoic cover with several major unconformities, rather different from the Mesozoic stratigraphy of the Istanbul Zone, unconformably overlies this basement (Okay 1987; Okay et al. 1994, 1996). The Istanbul Zone located along the western Black Sea coast consists of a continuous well-developed generally transgressive sedimentary sequence extending from the Ordovician into the Carboniferous. This Paleozoic sequence was folded and possibly thrust-faulted during the Late Carboniferous-Permian Hercynian Orogeny and was then unconformably overlain by Triassic and younger sedimentary rocks, particularly well developed east of Istanbul (Gedik 1975). The Paleozoic stratigraphy of the Istanbul Zone is unique in northwestern Turkey, where in situ pre-Permian sedimentary sequences are not known, and it bears close resemblance to the Moesian Platform (Okay et al. 1994, 1996) and the Brunovistulian Terrane of Central Europe (Kalvoda et al. 2003). According to Okay et al. (1994, 1996), the paleo-latitudes for Paleozoic and Triassic rocks of the Istanbul Zone are compatible with a location along the southern margin of Laurasia. To explain these features they suggested that the Istanbul Zone rifted from the southern margin of Laurasia during the Late Cretaceous. Yanev (1993), however, proposed that the "Moesian superterrane" has a Gondwanic or peri-Gondwanic origin according to paleoclimatic and paleomagnetic evidence as well as sedimentologic features.

The stratigraphic and sedimentologic characteristics of the Paleozoic sedimentary sequence around Istanbul–Gebze (Kocaeli) of the Istanbul Zone are different from that of the Eastern part of Gebze (Kocaeli). For example, the Upper Devonian is characterized, around Istanbul–Gebze (Kocaeli), by the sedimentary rocks of the pelagic facies. However, it is represented, in the East of Gebze, by the shelf facies. Therefore, Göncüoğlu & Kozur (1998) and Kozur & Göncüoğlu (1999) divided the "Paleozoic of Istanbul" into two terranes with different Paleozoic-Mesozoic histories: the Istanbul Terrane (Paleozoic-Mesozoic sequence around Istanbul–Gebze) and the Zonguldak Terrane (Çamdağ, Zonguldak, Amasra and Safranbolu regions). According to them, both terranes were north of peri-Gondwana during the early Paleozoic.

Although the Upper Devonian rocks are present in the Istanbul Zone of the Pontides, in the Taurides, and in the Border Folds, the rocks that represent pelagic facies are known only from the Istanbul Zone of the Pontides (Fig. 1). These rocks, belonging to the Ayineburnu Formation (Kaya 1973; Önalan 1982, 1988), are exposed in small and discrete outcrops due to the intense tectonic deformation. Some suitable sections are exposed at the Tuzla Peninsula, located approximately 30 km

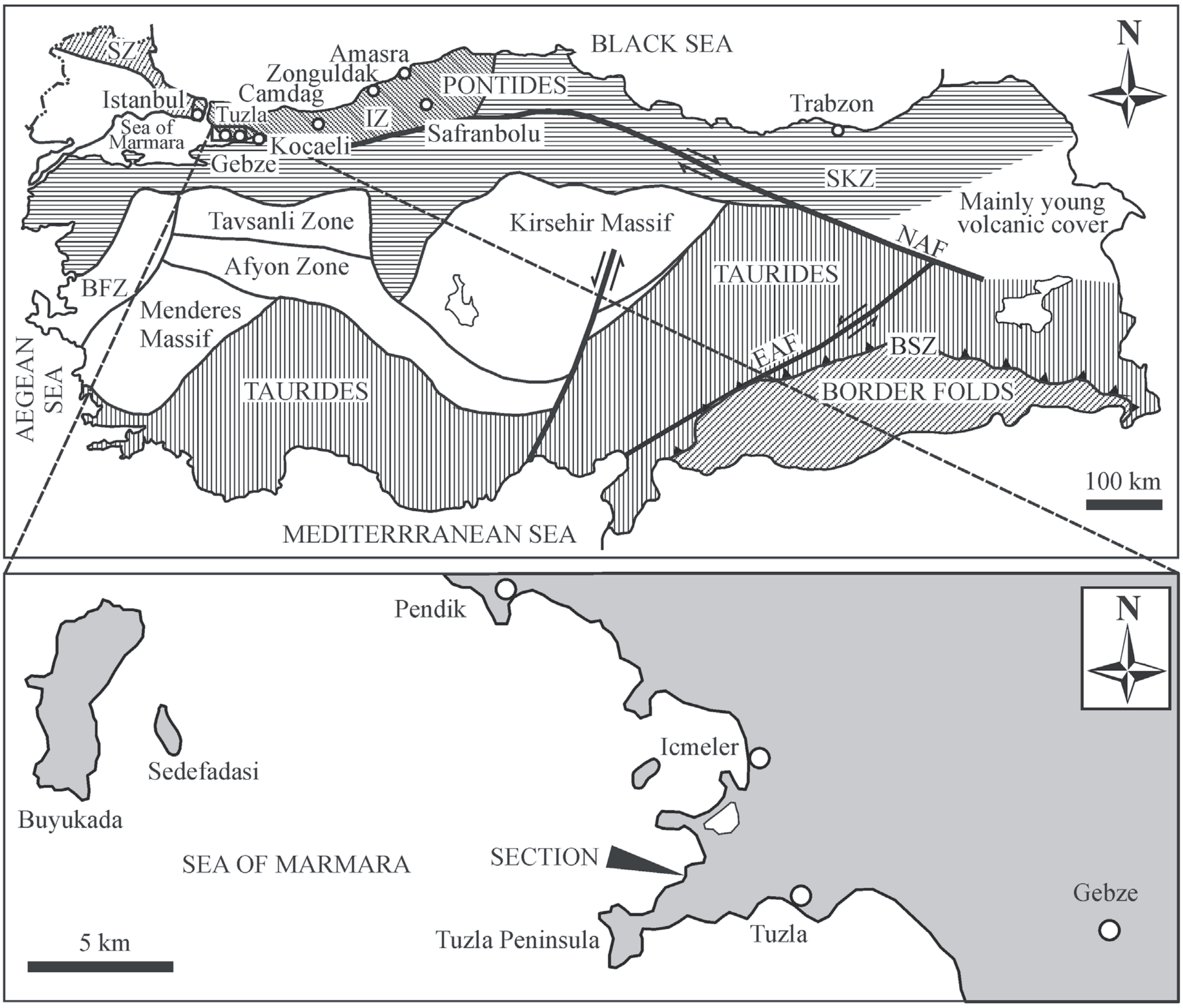

Fig. 1. Tectonic map of Turkey (Okay et al. 1994, 1996) and location map of the studied stratigraphic section. Explanations: **SZ** — Strandja Zone, **SKZ** — Sakarya Zone, **IZ** — Istanbul Zone, **NAF** — North Anatolian Fault, **BFZ** — Bornova Flysch Zone, **EAF** — East Anatolian Fault, **BSZ** — Bitlis Suture Zone.

southeast of Istanbul, northwestern Turkey (Fig. 1). Previously, Çapkınoğlu (1997, 2000) investigated some Upper Devonian conodont faunas from the Büyükada (Istanbul) and Gebze (Kocaeli) areas. The subject of the present paper is the description and biostratigraphic analysis of the conodont faunas obtained from an incomplete section of the Ayineburnu Formation exposed along the northern shore of the Tuzla Peninsula (Fig. 1). The first examinations of samples recovered from this section indicated evidence of the F/F boundary. However, the boundary interval corresponds to an unsampled part of the section due to lack of outcrop on the surface. A second attempt to sample the boundary interval proved impossible. The locality had been filled by the municipality to protect the area from sea waves.

Lithology and stratigraphy

Paleozoic rocks of the Istanbul Zone, which is generally accepted as a Hercynian fragment rifted from the southern margin of Laurasia during the Late Cretaceous (Okay et al. 1996), belong to an interval extending from the Ordovician into the Lower Carboniferous. The development during the Ordovician–early Visean reflects the transgressive, pre-flysch sedimentation of an Atlantic-type passive continental margin, turned into a Pacific-type active continental margin after the early Visean (Okay et al. 1994, 1996; Seymen 1995). The Upper Devonian Ayineburnu Formation studied herein is the part of this Paleozoic sequence. The Ayineburnu was first proposed by Kaya (1973) for exposures in Büyükada, Istanbul, where it is incomplete. It has been studied under different names, but first naming appropriate to stratigraphic rules was made by Kaya (1973). These strata were originally described by Haas (1968) as the "Denizli beds" of the Tuzla Formation from the Denizliköyü area, Kocaeli. Subsequently, Kaya (1973) introduced the name "Ayineburnu" for the outcrops of this unit in Büyükada, and assigned it to the Büyükada Formation to include the Bostancı, Yörükali, and Ayineburnu Members, respectively. Önalan (1982, 1988) incorporated these members into the Tuzla Formation, retaining the same names

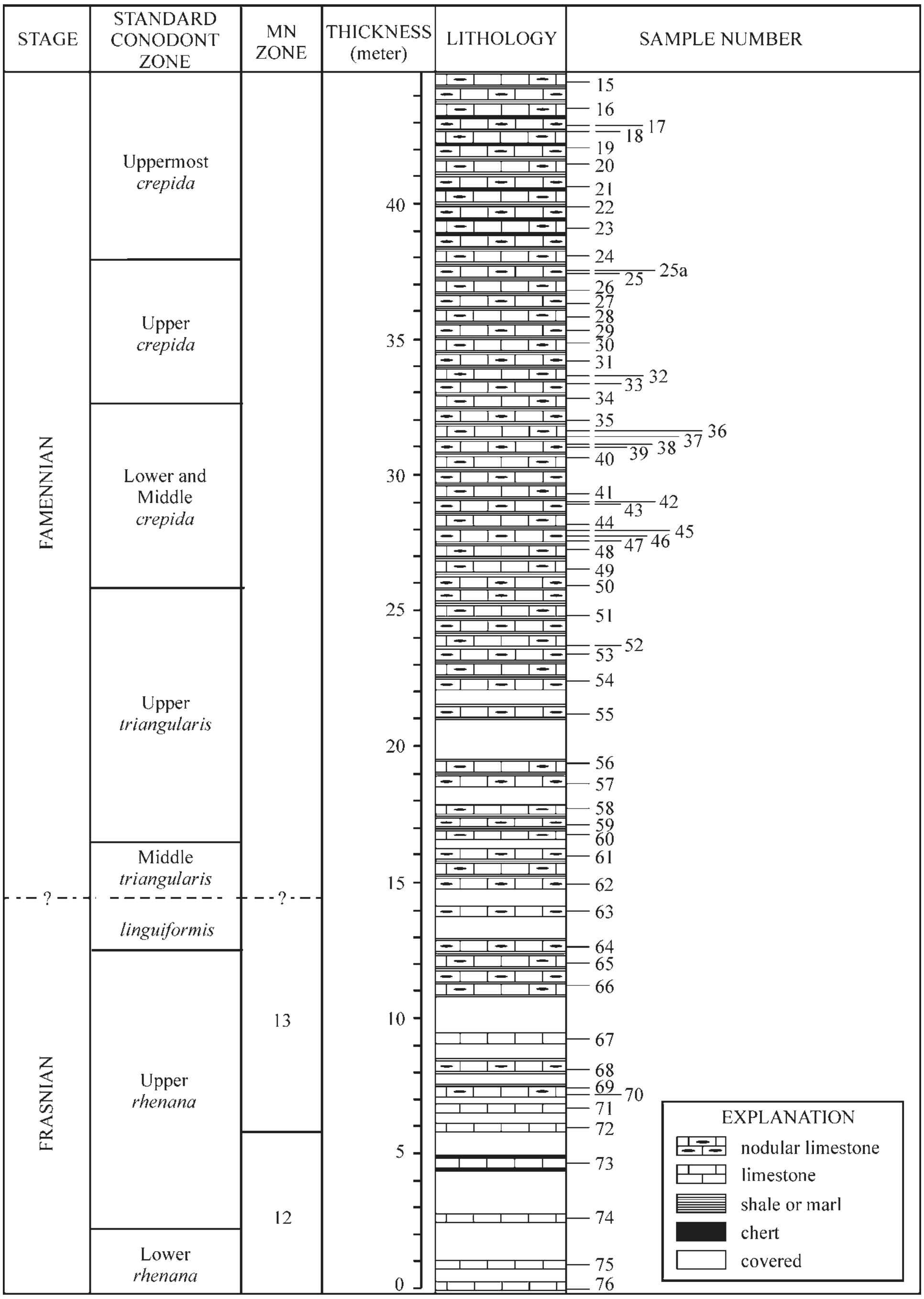

Fig. 2. Stratigraphic section showing lithology, sample locations, and standard conodont zones.

and boundaries. In this study the terminology of Kaya (1973) and Önalan (1982, 1988) has been followed due to their well-known and common use. However, based on their lithostratigraphic features, all members have been raised herein to formation rank. Detailed descriptions of these units are given in Kaya (1973) and Önalan (1982, 1988). In this study the Ayineburnu Formation is used as equivalent of the Ayineburnu Member in previous papers (Çapkınoğlu 1997, 2000).

Numerous exposures of the Ayineburnu Formation are faulted or covered by soil as indicated in previous papers (Çapkınoğlu 1997, 2000), therefore, accurate estimates of its thickness are currently impossible. The section studied is situated on the northern shore of the Tuzla Peninsula (topographic sheet 1/25000, Bursa G22-b4, approximately 30 km SE of Istanbul, 500 m NW of Köşk Tepe, and 15 m N of "the Tennis and Sea Club of Tuzla" (Fig. 1)). The section is about 45 meters thick (Fig. 2), and biostratigraphic analysis indicates that the whole sequence is overturned, dipping about 70° to the southwest. Soil and beach sediments cover the lower contact; the upper contact is fault-bound.

The lithology consists of bluish light grey to grey, nodular and bedded limestones, mainly mudstone and lesser wackestone, with yellowish light brown to beige shale partings, as well as black chert nodules and interbeds that become more prevalent in the upper parts of the sequence. The matrix is recrystallized in some samples. The limestones contain locally abundant ostracods, radiolarians, and rare brachiopods, as well as echinoderm and other fossil debris in a matrix of lime mud, where their abundance is less than 10 percent by volume. Tentaculites, generally restricted to the Frasnian samples, are abundant at certain levels, but are less common than ostracods. In acid residue, common ostracods, few tentaculites (homoctenids), rare brachiopods, and rare sponges were obtained along with the conodonts. Ostracods belong to the Thuringian ecotype, dominated by smooth and thin-shelled, often delicately to strongly spinose forms, which is generally considered to be indicative of low-energy environments, independent of paleo-depth and shoreline (Becker et al. 2003). Both sedimentary features (Önalan 1982, 1988) and conodont biofacies of the studied stratigraphic section suggest deposition in a basin slope setting.

Conodont biostratigraphy

57 of 63 limestone samples collected from the Ayineburnu Formation produced Late Devonian (late Frasnian and early Famennian) conodont faunas (Fig. 2; Tables 1 and 2). They generally represent the pelagic palmatolepid-polygnathid or palmatolepid biofacies correlating well with the standard Upper Devonian conodont zonation first proposed by Ziegler (1962) and updated by Ziegler & Sandberg (1990). Three of the upper Frasnian conodont zones extending from the Lower *rhenana* Zone into the *linguiformis* Zone, and six of the lower Famennian conodont zones extending from the Middle *triangularis* Zone into the Uppermost *crepida* Zone have been recognized.

Lower *rhenana* Zone — The conodont faunas of the samples 76 and 75 are nondiagnostic, and have been conditionally assigned to the Lower *rhenana* Zone. Overlying sample 74 is within the Upper *rhenana* Zone because it contains *Icriodus alternatus alternatus*, which first appears at or just after the start of this zone (Ziegler & Sandberg 1990, p. 21) (Table1).

Table 1: Distribution and abundance of Pa elements of conodont taxa in the studied stratigraphic section. See Fig. 2 for sample intervals. ***L. rh.*** — Lower *rhenana*, ***ling.*** — *linguiformis*, ***M. tr.*** — Middle *triangularis,* ***L.-M. cr.*** — Lower and Middle *crepida*, ***Pa.*** — *Palmatolepis*, ***Po.*** — *Polygnathus, **Ic.** — Icriodus, **Pe.** — Pelekysgnathus.*

Conodont zone	**L. *rh.***		**Upper *rhenana***									***ling.***		**M. *tr.***		**Upper *triangularis***										**L.-M. *cr.***	
Sample number (Tuzla)	**76**	**75**	**74**	**73**	**72**	**71**	**70**	**69**	**68**	**67**	**66**	**64**	**63**	**62**	**61**	**60**	**59**	**58**	**57**	**56**	**55**	**54**	**53**	**52**	**51**	**50**	**49**
Sample weight (kg)	**.40**	**.70**	**.65**	**.80**	**.80**	**.90**	**.60**	**.60**	**.80**	**.70**	**.70**	**.50**	**.70**	**.90**	**.70**	**.50**	**.55**	**.80**	**.85**	**.40**	**.75**	**.95**	**.90**	**.50**	**.75**	**1.2**	**75**
Pa. ederi	12	10	75	3	3		1?	3	5	1	2	10				12?											
Po. lodinensis	20	285	18	22					10	3	29	53				5											
Po. decorosus	3?				22	1		3	1	8		2															
Pa. sp. A	45	22	14	9	30			5																			
Pa. sp. C	6	11							3																		
Pa. sp. B		12	5	1	11				8			1															
Pa. jamieae		6	10	5	21	3		16	2																		
Ic. alternatus alternatus			4		5								3	3		1		43	59		6			7	14		
Ancyrodella ioides			4																								
Ancyrodella nodosa			2																								
Pa. hassi			4																								
Pa. winchelli				2	1			1	2				2														
Pa. rhenana				1																							
Pa. bogartensis					4			6	2	1	5	17	1														
Po. brevilaminus					10	1							2		4								5	3			
Pa. eureka					3			2		1		3															
Pa. mucronata					5			1																			
Pa. sp. E					8				2	2		4															
Ancyrognathus amana					2																						
Pa. juntianensis						1					1	10															
Pa. cf. *Pa. hassi*								1	1																		
Pa. sp. D									5			16	1														
Pa. linguiformis												2	1														
Ic. alternatus helmsi													1						7		1						
Pa. gigas													2														
Pa. triangularis														44	15	5		2		1			14		2		
Pa. clarki														19	7	4		10	1	1		1	1	1	2		
Pa. delicatula delicatula														10	1	2	1	2		1	1	1	8	2	4	2	
Pa. delicatula platys														2	2		3	1			1	2	16	4	1		
Pa. protorhomboidea														14			2	2		1		1	13		1		
Pa. subperlobata														7	2	7	1	5			1?		6		5	4	
Pa. minuta minuta																7	9	52	48	1	10	10	55	18	18	41	7
Pe. brevis																1											
Pa. lobicornis																		2	4		2			2	7		
Pa. regularis																		5	6	1	3		1	2		1	1
Pa. aff. *Pa. wolskae*																		2	7								
Po. glaber glaber																		4	2							1	
Ic. cornutus																		2	1		1		1				
Pa. aff. *P. adamantae*																									2		
Pa. tenuipunctata																										8	1
Pa. quadrantinodosalobata																										1	
Pe. inclinatus																										1	

Upper *rhenana* Zone — The base of this zone is defined by the first occurrence of *Palmatolepis rhenana rhenana* by Ziegler & Sandberg (1990). This species was not recognized in the present study, therefore the recognition of the lower boundary is based on the presence of *Icriodus alternatus alternatus* in sample 74 (Table 1). The lowest occurrence of *Palmatolepis linguiformis* in sample 64 defines the upper boundary.

Furthermore the lowest occurrence of *Palmatolepis bogartensis* in sample 72 defines the base of the Montagne Noire (MN) Zone 13 (Klapper 1989; Klapper & Becker 1999), and all strata containing the range of *Palmatolepis bogartensis* (samples 72–63) are within this zone (Fig. 2). The lower samples (76–73) can be tentatively assigned to the MN Zone 12 due to the absence of the defining taxa.

***Linguiformis* Zone** — The base is determined by the first appearance of *Palmatolepis linguiformis* in sample 64 (Table 1). Sample 63 with *Palmatolepis linguiformis* is also within this zone. The upper boundary is not detectable due to the lack of any taxa defining the base of the overlying Lower *triangularis* Zone.

Lower *triangularis* Zone — The Lower *triangularis* Zone is not documented in the studied stratigraphic section. The base of this zone, corresponding to the F/F boundary, is recognized by the first occurrence of *Palmatolepis triangularis* that is stratigraphically above the faunas dominated by late Frasnian species of *Palmatolepis*, *Ancyrognathus*, and *Ancyrodella* (Klapper et al. 1994). In the studied stratigraphic section, *Palmatolepis triangularis* first occurs together with *Palmatolepis delicatula platys* in sample 62, characteristic of the Middle *triangularis* Zone (Table 1). If the Lower *triangularis* Zone is not missing due to faulting, non-deposition or erosion, it must be restricted to the interval between samples 63 and 62 (Fig. 2).

Middle *triangularis* Zone — This zone is defined by the entry of *Palmatolepis delicatula platys* in sample 62, but its lower boundary may extend below this sample. The appearance of *Palmatolepis minuta minuta*, defining the upper boundary, is in sample 60 (Table 1).

Upper *triangularis* Zone — This zone starts with the first occurrence of *Palmatolepis minuta minuta* in sample 60, and extends to the first occurrences of *Palmatolepis quadrantinodosalobata* and *Pelekysgnathus inclinatus* in sample 50 (Table 1).

Lower and Middle *crepida* Zones — The base of the Lower *crepida* Zone has been defined by first occurrence of *Palmatolepis crepida* by Ziegler & Sandberg (1990). In the studied stratigraphic section, this species first occurs in sample 48. However, sample 50 contains the co-occurrence of *Palmatolepis quadrantinodosalobata* and *Pelekysgnathus inclinatus*, both of which first appeared at or near the start of the Lower *crepida* Zone (Ziegler & Sandberg 1990, p. 23; Schülke 1995, p. 28), and this occurrence indicates to the base of this zone for sample 50. The interval between the lowest occurrences of *Palmatolepis quadrantinodosalobata* with *Pelekysgnathus inclinatus*, and *Palmatolepis glabra unca* Sannemann (= *Palmatolepis glabra prima*) represents the Lower and Middle *crepida* Zones, and includes samples from 50 to 34 of the studied stratigraphic section (Tables 1, 2). The zonal indices for the boundary between these two zones are absent.

Table 2: Distribution and abundance of Pa elements of conodont taxa in the studied stratigraphic section. See Fig. 2 for sample intervals. ***Pa.*** *— Palmatolepis,* ***Po.*** *— Polygnathus,* ***Pe.*** *— Pelekysgnathus,* ***Me.*** *— Mehlina,* ***Ic.*** *— Icriodus.*

Conodont zone	**Lower and Middle *crepida***										**Upper *crepida***											**Uppermost *crepida***								
Sample number (Tuzla)	**48**	**47**	**46**	**45**	**42**	**40**	**39**	**38**	**36**	**35**	**34**	**33**	**32**	**31**	**30**	**29**	**28**	**27**	**26**	**25**	**25a**	**24**	**23**	**22**	**21**	**20**	**19**	**18**	**16**	**15**
Sample weight (kg)	**.75**	**.60**	**1.0**	**1.4**	**.90**	**.50**	**.80**	**.50**	**.85**	**1.0**	**.65**	**1.2**	**.80**	**.60**	**1.33**	**.90**	**.65**	**.65**	**.95**	**.70**	**.75**	**.80**	**.80**	**1.4**	**.50**	**.90**	**.80**	**1.2**	**.90**	**.85**
Pa. crepida	3		1												1?				1		2									
Pa. minuta minuta	13	1	5	4	2	10	34	3		1	3	2	8	6	50	18	8	19	24	8	32	7	1	20	7	15	4	4	2	7
Pa. quadrantinodosalobata	1	1	1			4							2	3	7	2	1	1	11	4	10	7	3	10	2	2				
Pa. tenuipunctata	2	1				2	5				1			1	1				1											
Po. procerus	3		2				1																							
Pe. inclinatus	1										1			1						1				1						
Pa. regularis			1	3		2	1	1							4	4	1?	2		4	1	2		1	3					
Po. lodinensis			3				1				1					1														
Pa. loba						1	3						2		6	4	3	2	3	3	5	1		3	2	1				
Pa. lobicornis							4		1		1	1?	3	4	8	3		3	16	2	4	3	7	2	4	8	1	2		1?
Po. glaber glaber							2													2	4	4	4	4	1		2			1
Pa. glabra unca											1		3	2	12	1	4	11	5	8	34	13	5	20	8	28	5	6	1	16
Pa. aff. *Pa. minuta subtilis*												1?	5	3	13	7	10	10	2		1	2			2					
Pa. aff. *Pa. adamantea*													1		2	2	1						2							
Pa. quadrantinodosalobata M1														1	2		1	8					2	5		3				
Me. strigosa														1	4	2	1	2			1	1		2	3	1				
Pa. schindewolfi															2			4	1?		1?			1?	2		1			1
Pe. planus															1						1									
Po. brevilaminus															2															
Pa. gracilis gracilis																2				1	5			2	2	6	1			
Ic. cornutus																		1?				2								
Po. nodocostatus nodocostatus																					1									
Pa. glabra pectinata M1																						1				1	1			
Pa. falcata																						2		2	1	2				1
Pa. glabra pectinata																							1	3		2				2
Pa. glabra acuta																								1		1?				1
Polylophodonta sp.																									1					
Pa. subgracilis																											1			
Po. semicostatus																														1

Upper *crepida* Zone — The first occurrence of *Palmatolepis glabra unca*, the defining taxon for the base of the Upper *crepida* Zone, is in sample 34 (Table 2). The upper boundary forming the base of the overlying Uppermost *crepida* Zone is based on the lowest occurrence of *Palmatolepis glabra pectinata* Morphotype 1 in sample 24.

Uppermost *crepida* Zone — The first occurrence of *Palmatolepis glabra pectinata* Morphotype 1 in sample 24 defines the base of the Uppermost *crepida* Zone. Higher samples (23–15) have been assigned to this zone due to lack of the diagnostic taxa representing the Lower *rhomboidea* Zone (Table 2).

Systematic paleontology

The sequence of conodont species in the studied stratigraphic section of the Ayineburnu Formation and their correlations with the standard Upper Devonian conodont zonation of Ziegler & Sandberg (1990) are given in Tables 1 and 2. Conodonts belong to Icriodontidae, Palmatolepididae, Polygnathidae, and Spathognathodontidae families, and the most abundant conodont genus is *Palmatolepis*. All taxa are illustrated in Figs. 3–6, and some are discussed below. The multielement notation and suprageneric classification used are those of Sweet (1988). Figured specimens and faunal slides are deposited at Department of Geological Engineering, Karadeniz Technical University, Trabzon, Turkey.

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

Palmatolepis aff. *P. adamantea* Metzger, 1994
Fig. 3.22,23

Remarks: The diamond-shaped platform outline, the broad semicircular parapet on inner side, the finely shagreen upper surface ornamentation, and the weakly developed posterior carina have been accepted as the most distinguishing features of the Pa element of *Palmatolepis adamantea* by Metzger (1994). Lack of a broad semicircular parapet on the anterior inner side distinguishes this species from the latter. *Palmatolepis* aff. *P. adamantea*, furthermore, has a longer free blade. In the Pa element of *Palmatolepis adamantea*, the anterior margin of the outer platform extends near to the anterior end of the free blade in contrast with *Palmatolepis* aff. *P. adamantea*.

Palmatolepis delicatula Branson et Mehl, 1934
Palmatolepis delicatula platys Ziegler et Sandberg, 1990
Fig. 3.16,17

1990 *Palmatolepis delicatula platys* Ziegler et Sandberg, p. 67–68, Pl. 17, Figs. 4–7 (synonymy)

Remarks: *Palmatolepis delicatula platys* is distinguished from *Palmatolepis delicatula delicatula* by having a more or less convex anterior outer platform margin, a concave posterior outer platform margin, and a more rounded outer lobe of Pa element. *Palmatolepis delicatula delicatula* has a straight or slightly concave outer anterior platform margin, and a more pointed outer lobe.

Palmatolepis ederi Ziegler et Sandberg, 1990
Fig. 5.11

1990 *Palmatolepis ederi* Ziegler et Sandberg, p. 62–63, Pl. 9, Figs. 1–7; Pl. 10, Figs. 6–10 (synonymy)

Remarks: The Pa element of this species can be confused with that of *Palmatolepis eureka* with a similar platform outline. They can be easily distinguished by the location on the blade-carina line of the central node. Although the central node is in the same line with the anterior and posterior carinas in *Palmatolepis ederi*, it exhibits a prominent lateral-offset due to the sharply deflection inwardly of the posterior carina in *Palmatolepis eureka*, and forms a sharp corner between the anterior and posterior carinas.

Palmatolepis hassi Müller et Müller, 1957
Fig. 5.12,13

1957 *Palmatolepis (Manticolepis) hassi* Müller et Müller, p. 1102–1103, Pl. 139, Fig. 2; Pl. 140, Figs. 2–4 (Fig. 4 = holotype)

Remarks: The specimens conform to description of Klapper & Foster (1993).

Palmatolepis jamieae Ziegler et Sandberg, 1990
Fig. 5.15,16

1990 *Palmatolepis jamieae* Ziegler et Sandberg, p. 50–51, Pl. 6, Figs. 1–10; Pl. 11, Figs. 4–6 (synonymy)

Remarks: Ziegler & Sandberg (1990) indicated two morphotypes, one with well-differentiated lobe and one with a poorly differentiated lobe of *Palmatolepis jamieae*. The present Pa elements generally belong to the second morphotype.

The Pa elements with a poorly differentiated lobe of this species can be confused to those of *Palmatolepis juntianensis*. However, the latter is distinguished by having a narrow and long anterior platform, and a characteristically straight posterior margin of the outer platform.

Palmatolepis lobicornis Schülke, 1995
Fig. 4.14–18

1995 *Palmatolepis lobicornis* Schülke, p. 40–41, Pl. 4, Figs. 1–17
1999 *Palmatolepis lobicornis* Schülke — Schülke,p. 40–41, Pl. 5, Figs. 1–14
2004 *Palmatolepis lobicornis* Schülke — Klapper, Uyeno, Armstrong et Telford, p. 379, Fig. 7.30 (synonymy)

Remarks: This species has been accepted as subspecies of *Palmatolepis subperlobata* by Ovnatanova (1976) and named as *Palmatolepis subperlobata helmsi.* Schülke (1995) assigned it to *Palmatolepis lobicornis* and Schülke (1999)

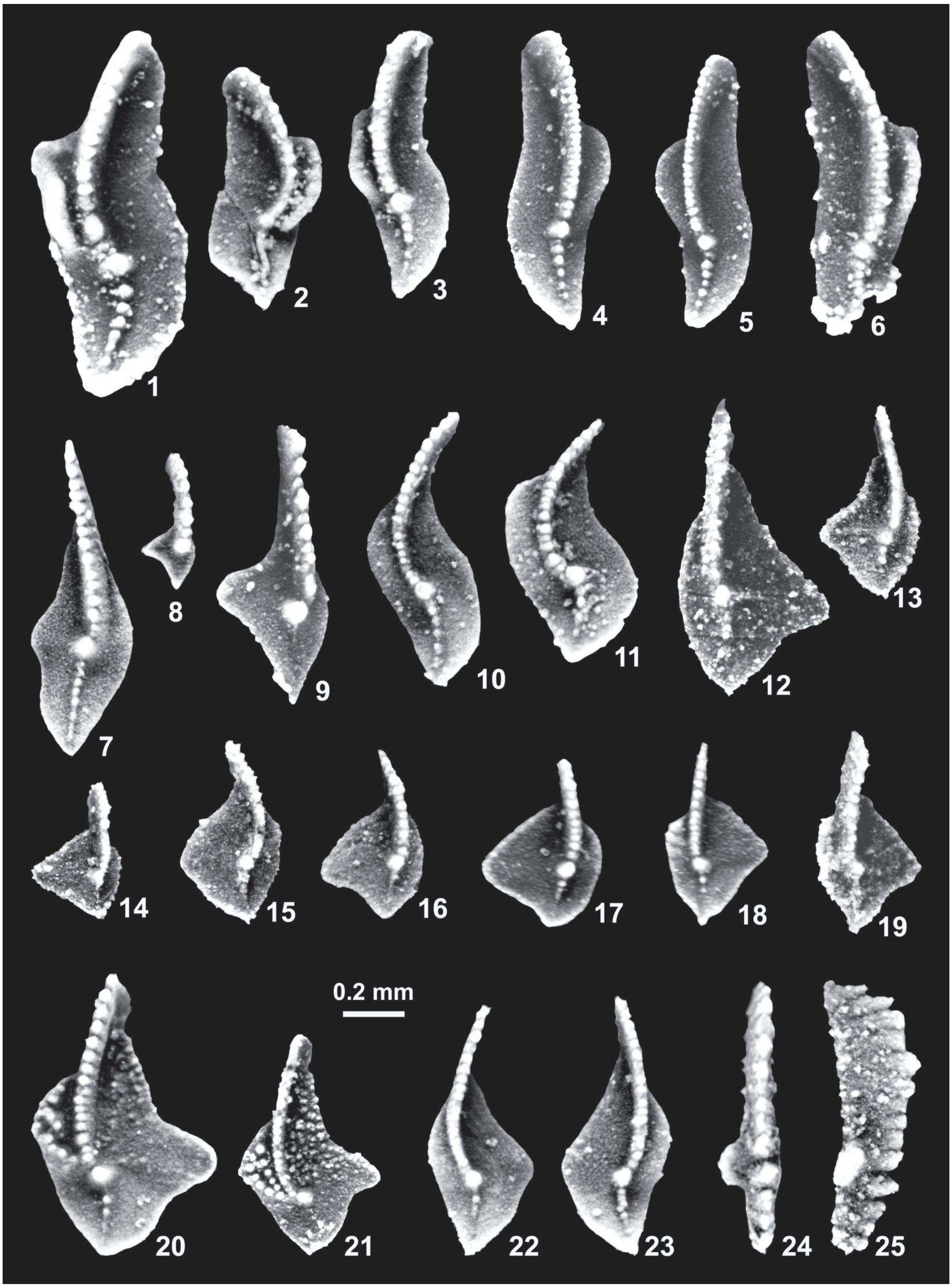

Fig. 3. Upper Devonian conodonts from the Tuzla Peninsula, the Istanbul Zone, NW Turkey. All upper views of Pa elements unless otherwise indicated. **1** — *Palmatolepis glabra pectinata* Ziegler, 1962, Morphotype 1; Tuzla 20. **2** — *Palmatolepis glabra pectinata* Ziegler, 1962; Tuzla 22. **3** — *Palmatolepis falcata* (Helms, 1959); Tuzla 24. **4–5** — *Palmatolepis glabra unca* Sannemann, 1955b (= *Palmatolepis glabra prima* Ziegler et Huddle, 1969); 4 — Tuzla 25a; 5 — Tuzla 25a. **6** — *Palmatolepis glabra acuta* Helms, 1963; Tuzla 15. **7** — *Palmatolepis minuta minuta* Branson et Mehl, 1934, Tuzla 25a. **8–9** — *Palmatolepis loba* Helms, 1963; 8 — Tuzla 40; 9 — Tuzla 25a. **10–11** — *Palmatolepis regularis* Cooper, 1931; 10 — Tuzla 24; 11 — Tuzla 38. **12–13** — *Palmatolepis clarki* Ziegler, 1962; 12 — Tuzla 57; 13 — Tuzla 51. **14–15** — *Palmatolepis delicatula delicatula* Branson et Mehl, 1934; 14 — Tuzla 51; 15 —Tuzla 62. **16–17** — *Palmatolepis delicatula platys* Ziegler et Sandberg, 1990; 16 — Tuzla 62; 17 — Tuzla 53. **18–19** — *Palmatolepis protorhomboidea* Sandberg et Ziegler, 1973; 18 — Tuzla 53; 19 — Tuzla 62. **20** — *Palmatolepis quadrantinodosalobata* Sannemann, 1955a; Tuzla 32. **21** — *Palmatolepis quadrantinodosalobata* Sannemann, 1955a, Morphotype 1; Tuzla 22. **22–23** — *Palmatolepis* aff. *P. adamantea* Metzger, 1994; 22 — Tuzla 29; 23 — Tuzla 28. **24–25** — *Palmatolepis subgracilis* Bischoff, 1956; upper and lateral views of same specimen; Tuzla 19. Scale bar = 0.2 mm.

proposed a multielement reconstruction for the species. As indicated by Klapper et al. (2004), her name is junior homonymy of *Palmatolepis helmsi* Ziegler, and therefore, the valid name is *Palmatolepis lobicornis* Schülke.

Platform outline of Pa element of *Palmatolepis subperlobata* is similar to that of *Palmatolepis triangularis*, differing only in ornamentation. Pa elements of present species have a longer outer lobe and generally straight posterior outer platform margin.

Palmatolepis aff. *P. minuta subtilis* Khalymbadzha et Chernysheva, 1978
Fig. 5.5–7

Remarks: The Pa element of *Palmatolepis minuta subtilis* is characterized by a narrow and long posterior platform with a sharply pointed posterior tip. The present Pa elements have a shorter and wider posterior platform with a blunt posterior tip distinguishing them from those of *Palmatolepis minuta subtilis*.

Palmatolepis mucronata Klapper, Kuz'min et Ovnatanova, 1996
Fig. 5.8,9

1996 *Palmatolepis mucronata* Klapper, Kuz'min et Ovnatanova, p. 147, Figs. 7.9–7.13 (synonymy)

Remarks: *Palmatolepis mucronata* is similar to *Palmatolepis rhenana* in general outline of the Pa element but differs by having a straight and extremely thin posterior carina that is directed sharply inward. The present Pa elements are closer to *Palmatolepis mucronata* by having a weakly developed posterior carina. The Pa elements of *Palmatolepis rhenana* have a well-developed posterior carina with large nodes.

Palmatolepis winchelli (= *P. subrecta*) (Stauffer, 1938)
Figs. 5.19, 6.11

1938 *Bryantodus winchelli* Stauffer, p. 423, Pl. 48, Fig. 33
1993 *Palmatolepis winchelli* (Stauffer) — Klapper et Foster, p. 24, 26, 31, Figs. 13.1–13.2, 18.1–18.8, 18.10–18.11, 19.6–19.12, 20.12–20.24 (see synonymy)

Remarks: Specimens assigned to this species are similar to *Palmatolepis gigas* in general outline and ornamentation of the Pa element but are characterized by a low unfortified rostral area on the outer anterior platform and a weak marginal fortification on the inner anterior platform as indicated by Ziegler & Sandberg (1990). *Palmatolepis gigas* has a rostrum that is strongly fortified on both sides of the anterior platform.

Palmatolepis sp. A
Fig. 6.4,5

Diagnosis: Pa element has a relatively narrow and long platform with a smooth upper surface, a weak lobe that is demarcated by deep anterior and weak posterior sinuses and directed anteriorly, and a pointed and downflexed posterior termination. Slightly sigmoidal carina does not extend to the posterior tip of the platform. Posterior outer margin is nearly straight or has very shallow sinus just posterior of lobe, followed by a slightly convex curve to posterior tip.

Remarks: The Pa element of *Palmatolepis ljaschenkoae* differs by having a wide, strongly convex posterior outer platform, a narrow anterior platform, and a well-developed outer lobe, which is demarcated by deep anterior and posterior sinuses. The anterior margin of the lobe is about at a right angle to carina. Posterior carina is deflected strongly laterally.

One of the specimens assigned to *Palmatolepis praetriangularis* by Savage & Yudina (2000: Pl. 1, Fig. 8) probably belong to this species.

Palmatolepis sp. B
Fig. 6.6–10

Diagnosis: Pa element has a more or less triangular platform with a short outer lobe directed laterally, and a moderately sigmoidal carina. The anterior margin of the outer platform varies from nearly straight in small specimens to slightly concave in larger specimens. The posterior margin of the outer platform is straight, or has a shallow sinus just posterior of lobe, followed by prominent convex curve to posterior tip. Platform is smooth or bears a few random nodes in large specimens. The posterior end is deflected downward.

Remarks: The Pa element of *Palmatolepis* sp. A has a narrower platform with a weak outer lobe directed anteriorly, and a sharply pointed posterior termination.

Palmatolepis sp. C
Fig. 6.1–3

Diagnosis: The Pa element of the large specimens has a triangular platform with strongly nodose margins and an outer lobe that is demarcated by shallow anterior and posterior sinuses. The anterior and posterior margins of the outer platform are slightly convex. Inner platform margin is a convex curve.

Remarks: Specimens assigned to this species are similar to *Palmatolepis winchelli* in the ornamentation of the Pa element but differ in the platform outline. Pa element of *Palmatolepis subrecta youngquisti* Savage with similar platform ornamentation has a longer free blade, and a longer platform with a sharply pointed outer lobe.

The Pa elements of *Palmatolepis* sp. C are rather similar to those of *Palmatolepis clarki*. They can be distinguished only by their inner platform outlines. In the Pa elements of *Palmatolepis clarki*, the inner platform outline is a convex curve that is the widest in the central-node position. The widest part of the inner platform in *Palmatolepis* sp. C has a more anteriorly position.

Palmatolepis sp. D
Fig. 6.13

Diagnosis: Pa element has an oval platform. Triangular outer platform has slightly convex anterior and posterior margins. Outer lobe is not developed. Posterior end is rounded. Inner platform margin is a convex curve extending from anterior

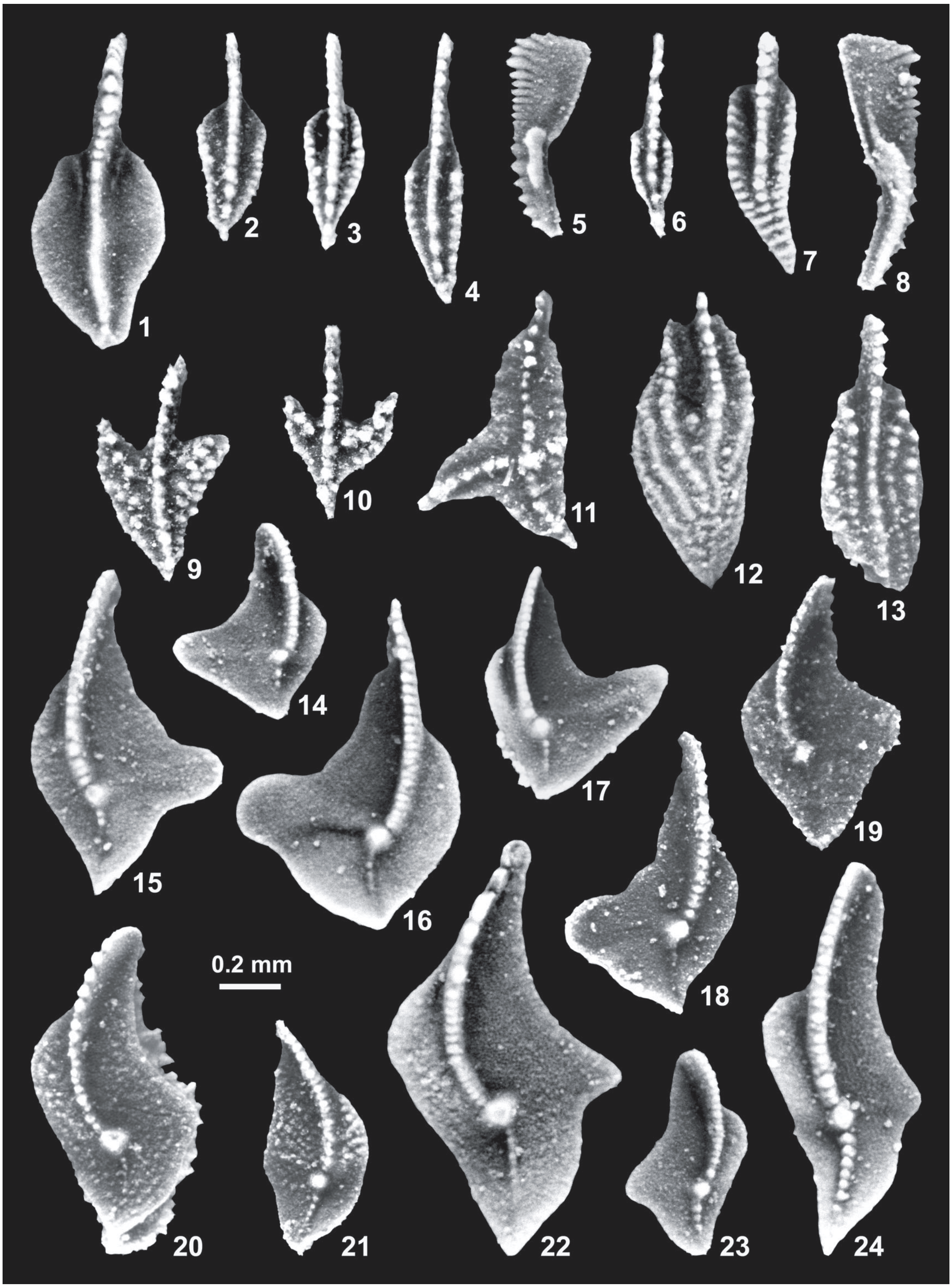

Fig. 4. Upper Devonian conodonts from the Tuzla Peninsula, the Istanbul Zone, NW Turkey. All upper views of Pa elements unless otherwise indicated. **1** — *Polygnathus glaber glaber* Ulrich et Bassler, 1926; Tuzla 24. **2–3** — *Polygnathus lodinensis* Pölsler, 1969; 2 — Tuzla 75; 3 — Tuzla 73. **4** — *Polygnathus decorosus* Stauffer, 1938; Tuzla 67. **5–6** - *Polygnathus brevilaminus* Branson et Mehl, 1934; 5 — Lateral view, Tuzla 30; 6 — Tuzla 72. **7** — *Polygnathus semicostatus* Branson et Mehl, 1934; Tuzla 15. **8** — *Polygnathus procerus* Sannemann, 1955b; Lateral view; Tuzla 48. **9** — *Ancyrodella nodosa* Ulrich et Bassler, 1926; Tuzla 74. **10** — *Ancyrodella ioides* Ziegler, 1958; Tuzla 74. **11** — *Ancyrognathus amana* Müller et Müller, 1957; Tuzla 72. **12** — *Polylophodonta* sp.; Tuzla 21. **13** — *Polygnathus nodocostatus nodocostatus* Branson et Mehl, 1934; Tuzla 25a. **14–18** — *Palmatolepis lobicornis* Schülke, 1995; 14 — Tuzla 22; 15 — Tuzla 51; 16 — Tuzla 32; 17 — Tuzla 20; 18 — Tuzla 26. **19** — *Palmatolepis* aff. *P. wolskae* Ovnatanova, 1969; Tuzla 57. **20–21** — *Palmatolepis crepida* Sannemann, 1955b; 20 — Tuzla 25a; 21 — Tuzla 48. **22** — *Palmatolepis perlobata schindewolfi* Müller, 1956; Tuzla 30. **23–24** — *Palmatolepis tenuipunctata* Sannemann, 1955b; 23 — Tuzla 50; 24 — Tuzla 31. Scale bar = 0.2 mm.

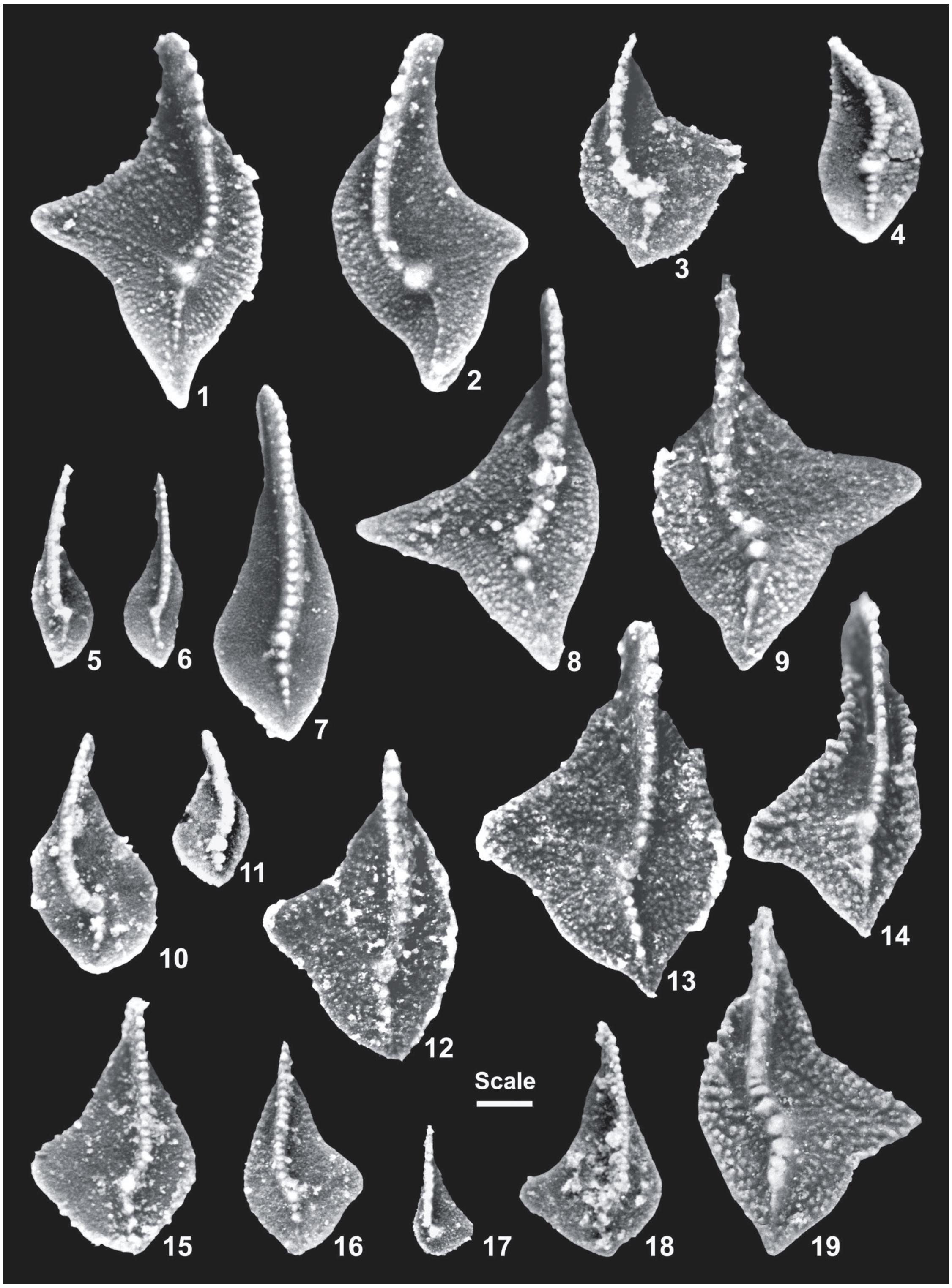

Fig. 5. Upper Devonian conodonts from the Tuzla Peninsula, the Istanbul Zone, NW Turkey. All upper views of Pa elements unless otherwise indicated. **1–2** — *Palmatolepis triangularis* Sannemann, 1955a; 1 — Tuzla 62; 2 — Tuzla 51. **3** — *Palmatolepis bogartensis* (= *P. rotunda*) (Stauffer, 1938); Tuzla 72. **4** — *Palmatolepis linguiformis* Müller, 1956; Tuzla 64. **5–7** — *Palmatolepis* aff. *P. minuta subtilis* Khalymbadzha et Chernysheva, 1978; 5 — Tuzla 27; 6 — Tuzla 28; 7 — Tuzla 28. **8–9** — *Palmatolepis mucronata* Klapper, Kuz'min et Ovnatanova, 1996; 8 — Tuzla 72; 9 — Tuzla 69. **10** — *Palmatolepis eureka* Ziegler et Sandberg, 1990; Tuzla 67. **11** — *Palmatolepis ederi* Ziegler et Sandberg, 1990; Tuzla 75. **12–13** — *Palmatolepis hassi* Müller et Müller, 1957; 12 — Tuzla 74; 13 — Tuzla 74. **14** — *Palmatolepis gigas* Miller et Youngquist, 1947; Tuzla 63. **15–16** — *Palmatolepis jamieae* Ziegler et Sandberg, 1990; 15 — Tuzla 69; 16 — Tuzla 69. **17–18** — *Palmatolepis juntianensis* Han, 1987; 17 — Tuzla 64; 18 — Tuzla 73. **19** — *Palmatolepis winchelli* (=*P. subrecta*) (Stauffer, 1938); Tuzla 63. Scale bar = 0.25 mm for figures 1, 3, 13, and 0.2 mm for others.

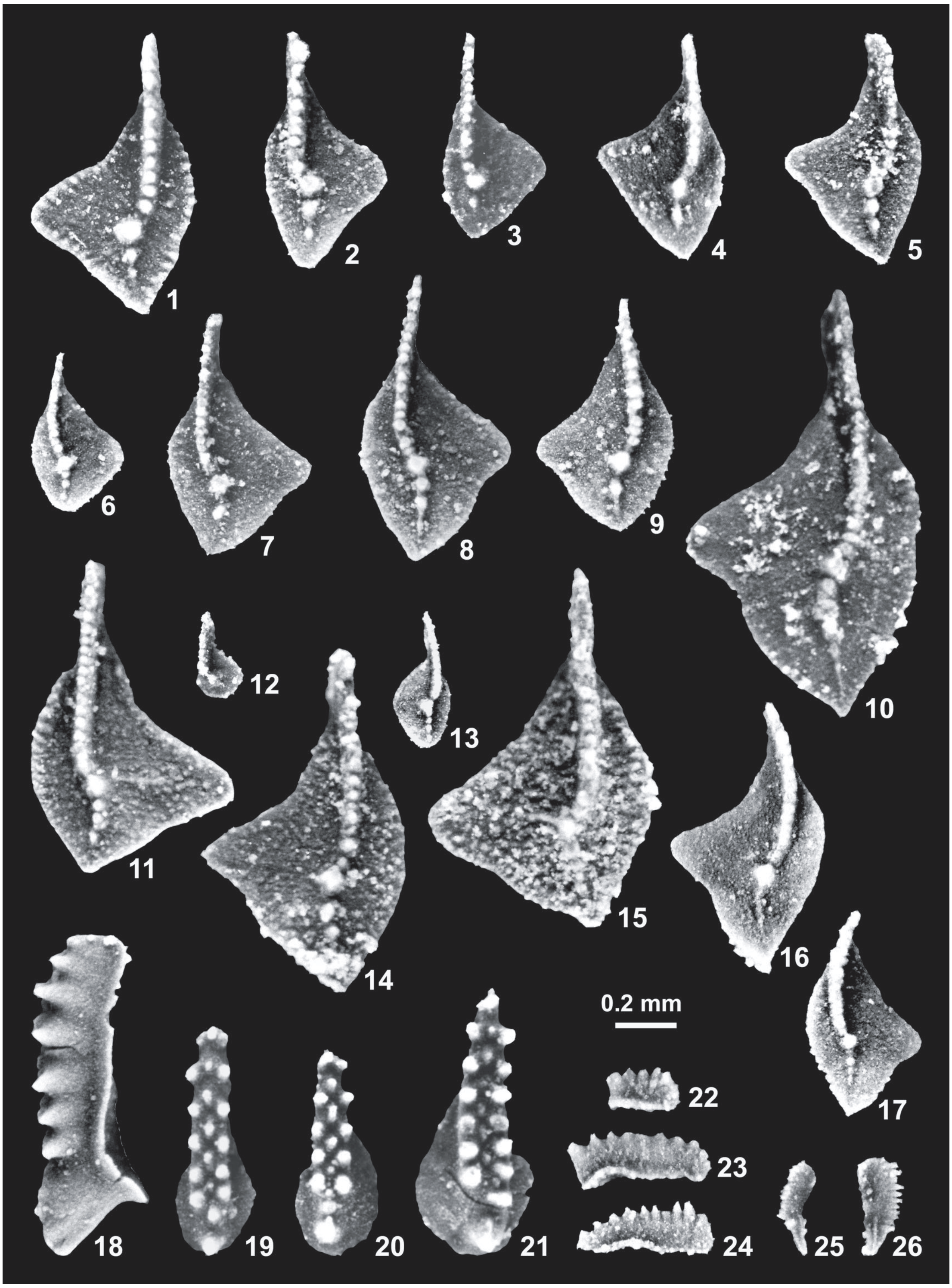

Fig. 6. Upper Devonian conodonts from the Tuzla Peninsula, the Istanbul Zone, NW Turkey. All upper views of Pa elements unless otherwise indicated. **1–3** — *Palmatolepis* sp. C; 1 — Tuzla 75; 2 — Tuzla 75; 3 — Tuzla 68. **4–5** — *Palmatolepis* sp. A; 4 — Tuzla 74; 5 — Tuzla 75. **6–10** — *Palmatolepis* sp. B; 6 — Tuzla 64; 7 — Tuzla 74; 8 — Tuzla 72; 9 — Tuzla 75; 10 — Tuzla 72. **11** — *Palmatolepis winchelli* (= *P. subrecta*) (Stauffer, 1938); Tuzla 68. **12** — *Palmatolepis* sp. E; Tuzla 64. **13** — *Palmatolepis* sp. D; Tuzla 64. **14–15** — *Palmatolepis* cf. *P. hassi* Müller et Müller, 1957; 14 — Tuzla 69; 15 — Tuzla 68. **16–17** — *Palmatolepis subperlobata* Branson et Mehl, 1934; 16 — Tuzla 60; 17 — Tuzla 50. **18** — *Icriodus cornutus* Sannemann, 1955b; Lateral view; Tuzla 24. **19–20** — *Icriodus alternatus alternatus* Branson et Mehl, 1934; 19 — Tuzla 57; 20 — Tuzla 57. **21** — *Icriodus alternatus helmsi* Sandberg et Dreesen, 1984; Tuzla 57. **22** — *Pelekysgnathus inclinatus* Thomas, 1949; Lateral view; Tuzla 50. **23** — *Pelekysgnathus planus* Sannemann, 1955b; Lateral view; Tuzla 30. **24** — *Mehlina gradata* Youngquist, 1945; Lateral view; Tuzla 21. **25–26** — *Palmatolepis gracilis gracilis* Branson et Mehl, 1934; 25 — Inner lateral view, Tuzla 21; 26 — Inner lateral view, Tuzla 20. Scale bar = 0.2 mm.

to posterior tip. Free blade is well developed. Carina is slightly sigmoidal.

Remarks: The Pa elements of *Palmatolepis ederi* and *Palmatolepis eureka* differ by having a strongly sigmoidal carina, a more ovate platform, and a short free blade. The present Pa elements have a longer free blade.

Palmatolepis sp. E
Fig. 6.12

Diagnosis: A nearly circular platform with a smooth upper surface, a moderately long and straight free blade, and a strongly sigmoidal carina are distinctive features of the Pa element. Posterior carina is absent or weakly developed.

Remarks: The present Pa elements may be the juveniles of *Palmatolepis juntianensis*. The Pa element of *Palmatolepis juntianensis* has an elongate platform with generally raised margins and a weakly developed outer lobe. In the Pa element of *Palmatolepis minuta elegantula* with a similar platform outline, the anterior margin of the outer platform is about at a right angle to the free-blade.

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

Polygnathus lodinensis Pölsler, 1969
Fig. 4.2,3

1969 *Polygnathus lodinensis* Pölsler, p. 425–426, Pl. 6, Figs. 1–12
1989 *Polygnathus lodinensis* Pölsler — Klapper et Lane, Pl. 2, Fig. 1

Remarks: *Polygnathus lodinensis* is the most common *Polygnathus* species in the studied stratigraphic section. Distinctive characteristics of the Pa element of this species are a strongly arched platform, a short free-blade with about half-length of the platform, and a sharply pointed posterior tip. The Pa elements of *Polygnathus timanicus* are distinguished from this species by very prominent convex bowing of the inner anterior platform margin, which makes the platform highly asymmetrical, and a rounded posterior tip. The Pa element of *Polygnathus decorosus* has a longer free blade, and a more symmetrical platform.

Genus: *Polylophodonta* Branson et Mehl, 1934a
Type species: *Polygnathus gyratilineatus* Holmes, 1928

Polylophodonta sp.
Fig. 4.12

Diagnosis: Pa element has a platform with well-developed rostral ridges in the anterior two-thirds, and irregular transverse ridges in the posterior one-third. There are three rostral ridges on the outer platform that are parallel each other, and only one rostral ridge on the inner platform. They are separated by wide adcarinal troughs from the carina, and parallel the carina anteriorly and diagonal it posteriorly. The carina changing widely spaced nodes posteriorly does not arrive to the posterior tip of the platform.

Remarks: The species is treated in open nomenclature because only a single specimen was found.

Conclusions

Three of the standard upper Frasnian conodont zones (Lower *rhenana* to *linguiformis*) and six of the standard lower Famennian conodont zones (Middle *triangularis* to Latest *crepida* Zone) of Ziegler & Sandberg (1990) have been recognized from dark grey, generally nodular limestone beds of the Ayineburnu Formation (Fig. 2). The Lower *triangularis* Zone and F/F boundary have not been recognized in the studied stratigraphic section. There is an unsampled interval of about one meter between samples 63 (the *linguiformis* Zone) and 62 (the Middle *triangularis* Zone), which is generally covered by recent sediments (Fig. 2). This interval can partly represent the Lower *triangularis* Zone, and includes the F/F boundary. However, the assign is questionable due to the absence of the zonal name bearer taxa. Furthermore, most of the conodont faunas from the lowest Famennian strata (samples 62–60) are densely covered by matrix, hindering the determination of specimens, suggesting a reworking.

The F/F boundary interval in some other locations in the world is characterized by a hiatus, caused by the absence of the Lower *triangularis* Zone or the complete *triangularis* Zone. Horizons of non-deposition and gaps were often found in shallow water sediments (Metzger 1989; Piecha 2002; Over 2002). In the South Polish Moravian shelf basins, the Lower *triangularis* Zone is at least conspicuously reduced in thickness, even in the distal slope to basinal sequences, and a thinning is also noted in the Middle *triangularis* Zone (Racki et al. 2002). In some sections of the basinal facies from Germany, the Lower *triangularis* Zone is thinner from one meter (see Sandberg et al. 1988; Ziegler & Sandberg 1990).

In the studied stratigraphic section, the appearance of *Palmatolepis crepida*, defining the base of the Lower *crepida* Zone, is some above the base of this zone as in many sections in the world (Schülke 1995, p. 28), and therefore the lower boundary has been recognized by the first occurrences of *Palmatolepis quadrantinodosalobata* and *Pelekysgnathus inclinatus*, as indicated by Schülke (1995, p. 28). The boundary between the Lower and Middle *crepida* Zones could not also be determined due to the lack of the defining taxa (Table 2).

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