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A pelagic Upper Devonian sequence in Sarıyer, İstanbul

Aral I. OKAY[1,2,*], **Ayşe ATAKUL-ÖZDEMİR**[3], **Nilgün OKAY**[2]
[1]Eurasia Institute of Earth Sciences, İstanbul Technical University, İstanbul, Turkey
[2]Department of Geology, Faculty of Mines, İstanbul Technical University, İstanbul, Turkey
[3]Department of Geophysical Engineering, Van Yüzüncü Yıl Üniversitesi, Van, Turkey

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Abstract: The Palaeozoic sequence in the İstanbul region is made up of a continuous transgressive sedimentary series extending from Ordovician continental clastic rocks to Lower Carboniferous turbidites. The middle part of this sequence consists predominantly of carbonates ranging from shallow marine Upper Silurian limestones to latest Devonian to earliest Carboniferous deep marine limestones and shales. Here, we describe a new Upper Devonian deep marine limestone-siltstone section from the Sarıyer region in the European part of İstanbul. The 37-m thick section located in the campus of the İstanbul Technical University consists at the base of dark micritic limestones interbedded with carbonate-rich siltstones, which pass up into siltstones with rare micritic limestone lenses and beds. Conodonts indicate a late Famennian (latest Devonian) age for the İTÜ campus section; 5 conodont biozones are documented; *Pseudopolygnathus granulosus*, *Polygnathus styriacus, Palmatolepis gracilis manca, Palmatolepis gracilis expansa*, and *Bispathodus aculeatus aculeatus*. The Late Devonian fauna from the İTÜ Campus section are dominated by the important marker species of *Palmatolepis, Bispathodus* and *Polygnathus*. There are also some *Branmehla, Mehlina,* and *Icriodus* elements within the succession. The conodont assemblages are representative of the palmatolepid-bispathodid biofacies, which indicate deposition on an outer shelf to slope environment.

Key words: İstanbul Zone, Devonian, Famennian, conodont, Ayineburnu Formation

1. Introduction

The İstanbul region is characterized by a thick (>7 km), continuous transgressive Palaeozoic sedimentary sequence, which has been studied since the 19th century (e.g., Paeckelman, 1939; Okay, 1947; Haas, 1968; Kaya, 1973; Önalan, 1988; Özgül, 2011; 2012, Figures 1 and 2). At the base of the Palaeozoic sedimentary sequence, there are Ordovician lacustrine mudstone and siltstone (the Kocatöngel Formation), which are overlain by fluvial conglomerate, sandstone and mudstone (the Kurtköy Formation); these fluvial series pass up into the Ordovician quartzites (the Aydos Formation), which make up most of the large hills in İstanbul. The quartzites are overlain by a sequence of siltstone, shale and sandstone (the Gözdağ Formation) with Late Ordovician–Early Silurian acritarchs, conodonts and brachiopods (cf. Özgül, 2011). The Gözdağ Formation passes up into Upper Silurian–Lower Devonian shallow marine limestones (the Dolayoba Formation), which are overlain by Lower Devonian fossiliferous shales and siltstones. This Kartal Formation is overlain by Middle Devonian–Lower Carboniferous deep marine limestones and shales, which pass up into Lower Carboniferous (Tournaisian) black radiolarian cherts (the Baltalimani Formation). A thick sequence of Carboniferous greywacke-type sandstones and shales (the Trakya Formation) lie over the black cherts.

The Upper Devonian and lowermost Carboniferous in the İstanbul region are represented by the basinal nodular limestones and shales of the Ayineburnu Formation, which crop out both on the European (Çatalca Peninsula) and on the Anatolian sides (Kocaeli Peninsula) of İstanbul (Kaya, 1971, 1973; Özgül, 2011, 2012). The conodonts in the Ayineburnu Formation are studied in several measured stratigraphic sections on the Kocaeli Peninsula (Figure 1, Çapkınoğlu, 1997, 2000, 2005a, 2005b; Göncüoğlu et al., 2004). On the other hand, there is no information on the precise age and lithology of the Ayineburnu Formation in the European part of İstanbul. Here we report new stratigraphic and paleontological data from a new Upper Devonian stratigraphic section on the European part of İstanbul and discuss is it within the frame of the Upper Devonian stratigraphy of the İstanbul Zone and Late Devonian conodont biostratigraphy.

* Correspondence: okay@itu.edu.tr

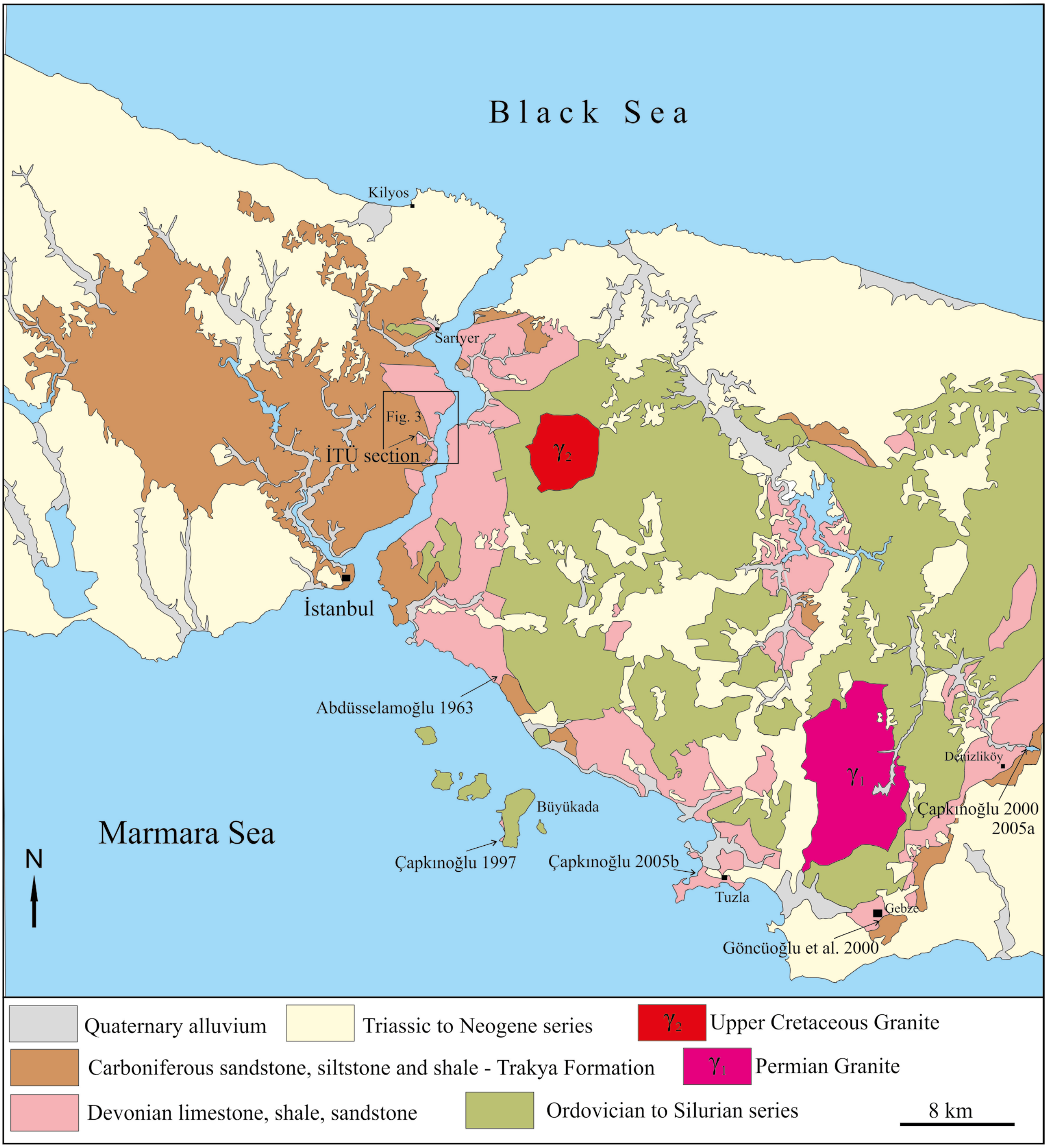

Figure 1. Geological map of the İstanbul region. Simplified and compiled from Özgül (2011), Duru and Pehlivan (2010), and Pehlivan and Duru (2010).

2. The geology and stratigraphy of the Upper Devonian İTÜ Campus section

Most of the European part of İstanbul is underlain by the sandstones and siltstones of the Carboniferous Trakya Formation (Figure 1, N. Okay et al., 2011). Only towards the Bosporus, older formations crop out under the Trakya Formation (Kaya, 1973; Gedik et al., 2005). Because of the heavy urbanization and dense vegetation, contacts between the formations are rarely observed, and when observed, the contacts are generally faulted. The section studied is located in the district of Sarıyer within the Maslak Campus of the Istanbul Technical University (Figures 1 and 3). The

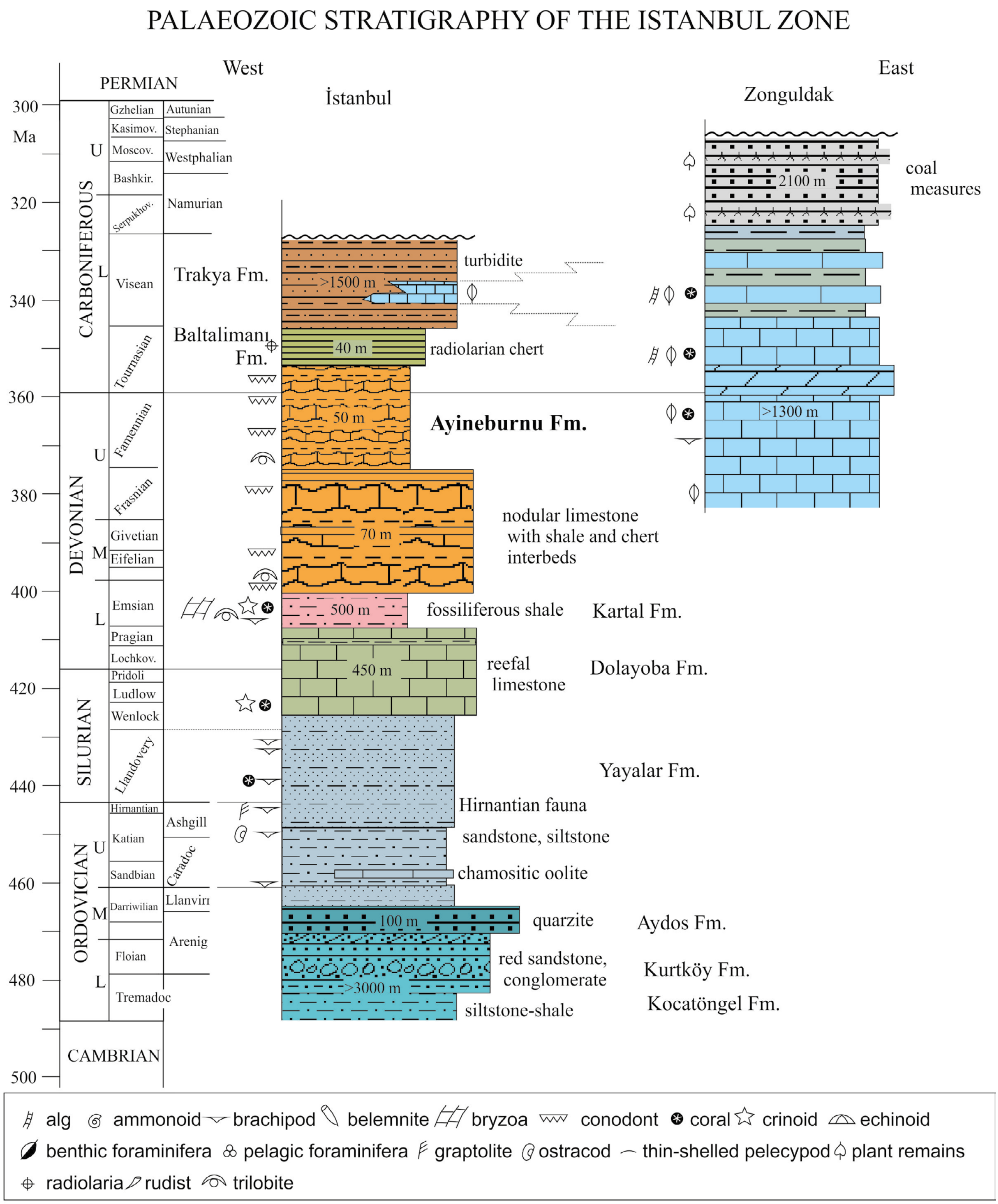

Figure 2. Palaeozoic stratigraphic section of the İstanbul Zone (modified from Okay and Nikishin, 2015). The stratigraphic and paleontological data are from Dil et al. (1976), Özgül (2012), and Sayar and Cocks (2013). The geological time scale is after Ogg et al. (2008).

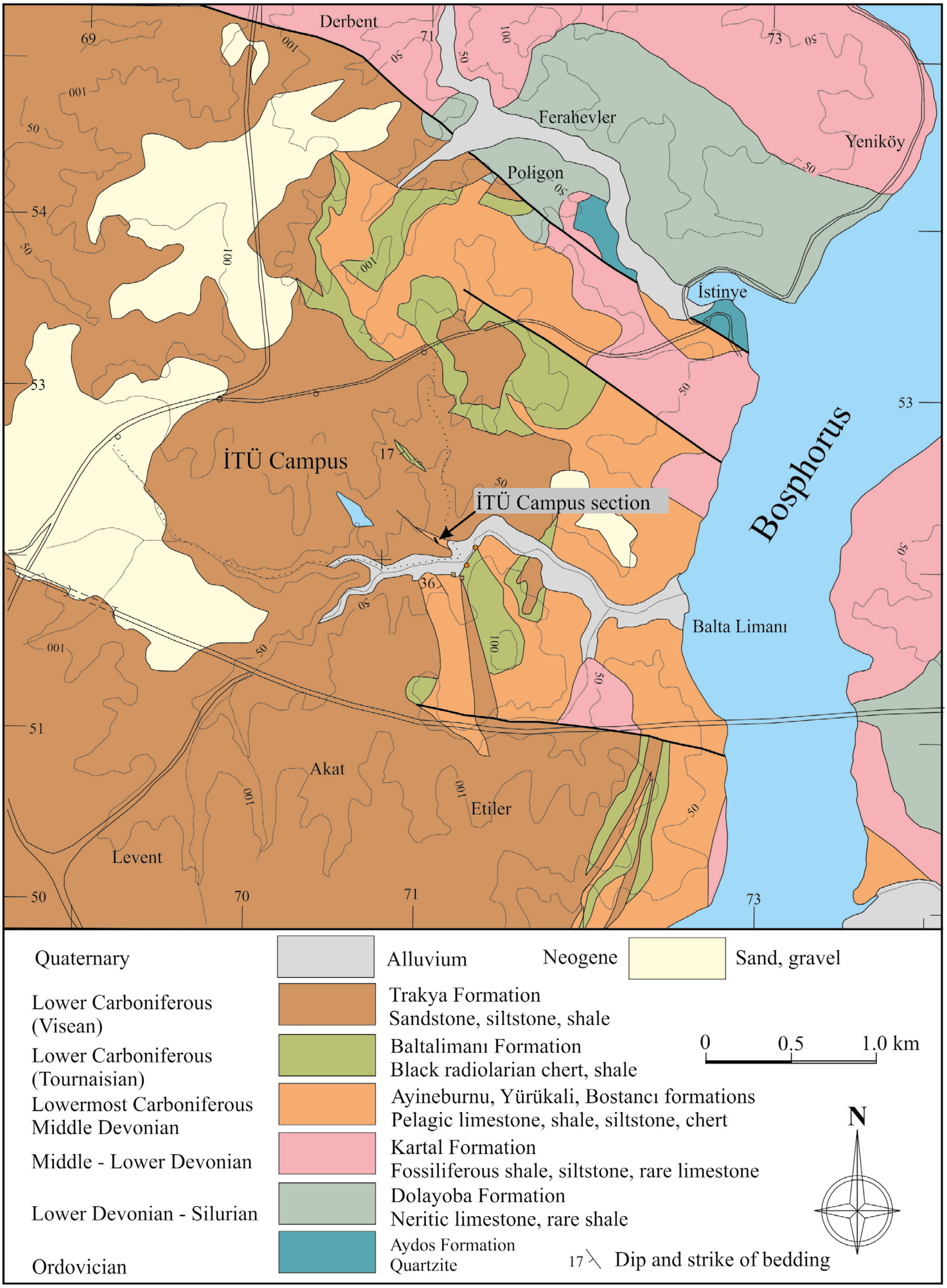

Figure 3. Geological map of the İstinye-Maslak area, İstanbul showing the location of the İTÜ Campus section. The map is based on Kaya (1971, 1973), Gedik et al. (2005), and our own work.

section is a newly opened road cut on the south-eastern corner of the İTÜ Campus. The İTÜ Campus section is 37-m thick with a faulted contact at the top (Figures 4 and 5a); the lower contact is obscured by vegetation and talus.

The İTÜ section is divided into three parts. At the base there is a 3-m-thick dark grey, massive, nodular limestone with fused bedding (Figure 5b) The limestone is overlain through a shale interval by a 6-m-thick sequence of thinly bedded (2–3 cm bed thickness) dark grey, locally nodular limestone with intercalations of carbonate-rich siltstone (Figure 5c). Petrographically, the limestones are carbonate mudstones with rare thin-shelled bivalve fragments. The limestone-siltstone sequence passes up into a 29-m-thick series of thinly bedded dark grey to dark greenish brown, carbonate-rich siltstones with rare lensoid silty limestone beds, which occur towards the top of the siltstone series (Figures 4 and 5d). The carbonate content of the siltstones decreases towards the top of the section, where the siltstones consist of quartz, feldspar, mica, and clay minerals (Figure 5e). They are in faulted contact with the thickly bedded sandstones and siltstones of the Trakya Formation (Figure 5a).

3. Conodont biostratigraphy

The Late Devonian conodont zonation was originally constructed in the pelagic biofacies and was subdivided

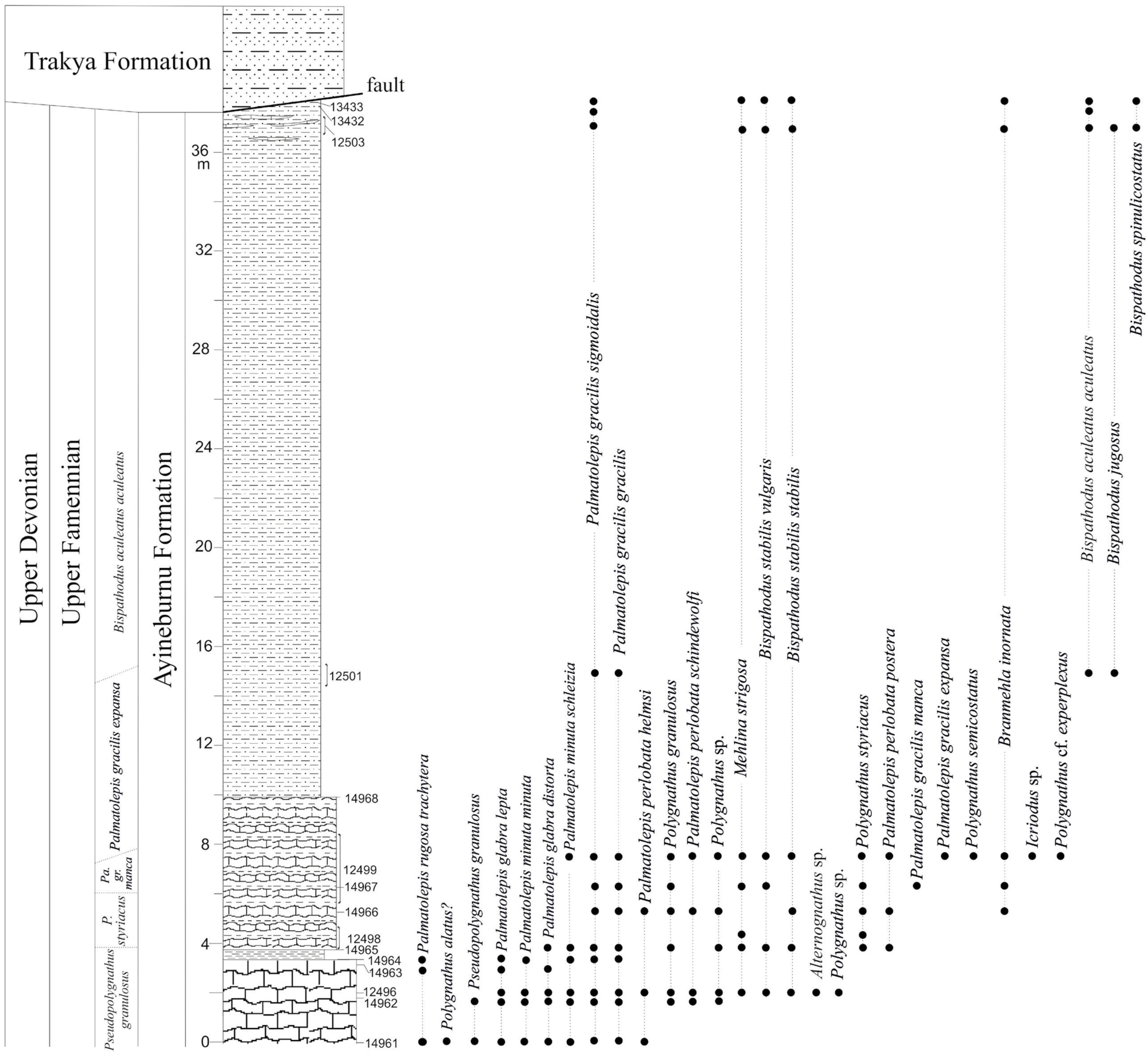

Figure 4. The İTÜ Campus section in the Ayineburnu Formation with the stratigraphical distribution of conodont species and the upper Famennian conodont zonation. For location see Figures 1 and 2.

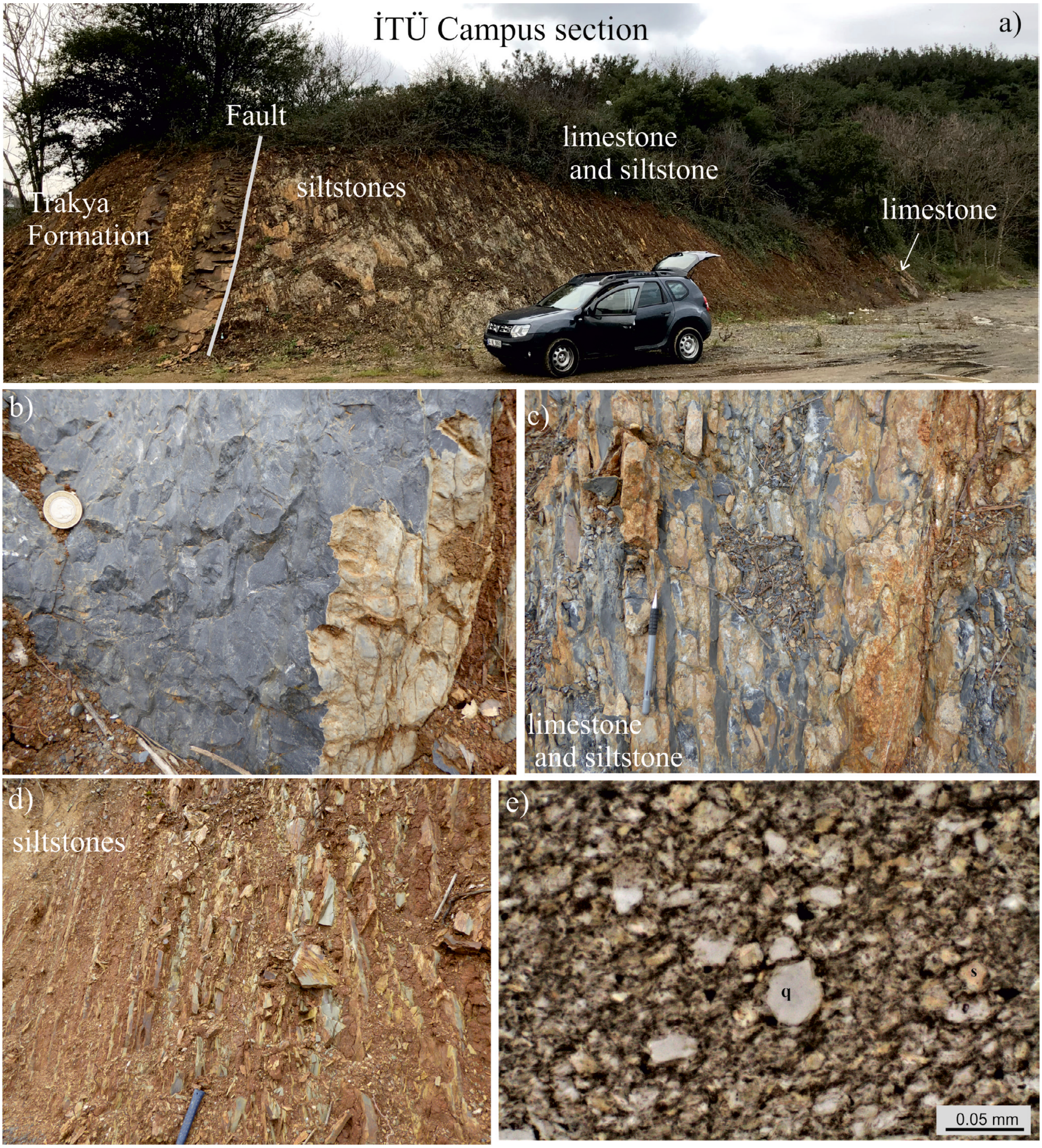

Figure 5. Field and micro photographs of the İTÜ Campus section. a) General view of the İTÜ Campus section. b) Dark grey nodular upper Famennian limestones with fused bedding at the base of the section. c) Light grey locally nodular limestones and dark grey carbonate-rich siltstones. d) Thinly bedded siltstones in the upper part of the İTÜ Campus section. e) Microphotograph in plane-polarized light of the siltstone from the upper part of the İTÜ campus section. The siltstone consists of quartz (q), sericitized feldspar (s), opaque and clay minerals. Note the lack of calcite and the grain size define a siltstone rather than a shale.

into 28 zones based on *Palmatolepis* (Ziegler, 1962; Ziegler and Sandberg, 1984, 1990). Modifications to the Late Devonian conodont zonation were later suggested by Corradini (2008), Kaiser et al. (2009), Hartenfels (2011), and Spalletta et al. (2017). For this study, the "Late Devonian Standard Conodont Zones" proposed by Ziegler and Sandberg (1990) and later updated by Spalletta et al. (2017) have been followed (Figure 6).

The conodonts from the Ayineburnu Formation in the İstanbul area were first described by Abdülselamoğlu (1963); detailed conodont biostratigraphy of the Ayineburnu Formation was studied by Çapkınoğlu (1997, 2000, 2005a, 2005b and Göncüoğlu et al. (2004). Çapkınoğlu (1997) described the Upper *rhomboidea* and Lower *marginifera* zones within the formation in the Büyükada section. Çapkınoğlu (2000, 2005a) documented the Lower *magnifera* through the Upper *expansa* zones from incomplete sections in the Denizliköyü area in Gebze. Çapkınoğlu (2005b) recognized the Upper *rhenana* to the uppermost *crepida* zones from the Tuzla area. Göncüoğlu et al. (2004) studied the uppermost layers of the Ayineburnu formation in the Gebze area and recorded the conodont elements characterizing the interval from the upper part of the *sandbergi* zone to the *isosticha*-Upper *crenulata* zone, specifying the first discovery of Middle Tournaisian conodonts from the Ayineburnu Formation.

The studied interval at İTÜ Campus section contains important and typical late Famennian (latest Devonian) conodonts including *Palmatolepis, Polygnathus, Bispathodus, Branmehla, Mehlina*, and *Icriodus*. Most abundant are the species of *Palmatolepis, Bispathodus*, and *Polygnathus*, which are common throughout the whole section. Other Late Devonian genera including *Branmehla* and *Mehlina* occur in smaller numbers, and representatives of the genera *Icriodus* and *Alternognathus* are very rare. Conodont elements are diverse and abundant in the samples (14961, 14962, 12496, 14963, 14964, 14965, 12498, 14966, 14967, 12499) from the lowermost part of the section; diversity and species richness decrease towards the upper part of the section, and the samples 12501, 12503, 12532, and 12534 yielded relatively poor elements averaging less than 10 to 15 specimens per kg.

A total of 25 species and subspecies belonging to seven conodont genera have been identified in the İTÜ Campus section, which indicate a late Famennian age. Based on the appearance and disappearance of biostratigraphically significant taxa, five conodont biozones are documented, which are *Pseudopolygnathus granulosus*, *Polygnathus styriacus, Palmatolepis gracilis manca*, *Palmatolepis gracilis expansa*, and *Bispathodus aculeatus aculeatus* zones (Figure 4).

3.1 *Pseudopolygnathus granulosus* zone

The interval at the base of the section (between samples 14961–14964) before the first occurrence of *Polygnathus styriacus* is determined as the *Pseudopolygnathus granulosus* Zone. The upper boundary of this zone is delineated by the first appearance of *Polygnathus styriacus.* The zone is characterized by the occurrence of the species *Pseudopolygnathus granulosus, Palmatolepis rugosa trachytera*, and *Palmatolepis gracilis sigmoidalis* in this interval (Figure 4). The accompanied fauna includes *Alternognathus* sp., *Bispathodus stabilis vulgaris* (morphotype 1), *Bispathodus stabilis stabilis* (morphotype 2), *Mehlina strigosa*, *Palmatolepis glabra lepta, Palmatolepis gracilis gracilis, Palmatolepis minuta minuta, Palmatolepis minuta schleizia*, *Palmatolepis perlobata helmsi*, *Palmatolepis perlobata schindewolfi*, *Polygnathus granulosus*, and *Polygnathus* sp. (Figures 7 and 8).

Hartenfels (2011) partitioned the Upper *trachytera* zone into three subzones as *Pseudopolygnathus granulosus, Palmatolepis gracilis sigmoidalis*, and *trachytera–styriacus* Interregnum (Figure 6). *Pseudopolygnathus granulosus* subzone and *Palmatolepis gracilis sigmoidalis* subzone have been designated by successive first appearances of the nominative species and the *trachytera–styriacus* Interregnum is the zone between the disappearance of *Palmatolepis rugosa trachytera* and the first appearance of *Polygnathus styriacus* (Hartenfels, 2011). In the studied section, the species *Palmatolepis rugosa trachytera, Palmatolepis minuta minuta*, and *Palmatolepis glabra lepta* become extinct at the top of this zone (Figure 4).

The *Pseudopolygnathus granulosus* zone is equivalent to the Upper *trachytera* zone of Ziegler and Sandberg (1990), *Pseudopolygnathus granulosus* zone of Spalletta et al. (2017) and *Palmatolepis gracilis sigmoidalis* subzone to *trachytera–styriacus* Interregnum of Hartenfels (2011) (Figure 6).

3.2 *Polygnathus styriacus* zone

The zone is defined by the first appearance of *Polygnathus styriacus* and *Palmatolepis perlobata postera*, which are used as zonal markers in the samples 14965, 12498, and 14966 (Figure 4). The associated fauna is characterized by *Bispathodus stabilis vulgaris* (morphotype 1), *Bispathodus stabilis stabilis* (morphotype 2), *Mehlina strigosa*, *Palmatolepis gracilis sigmoidalis, Palmatolepis gracilis gracilis, Palmatolepis minuta schleizia*, *Palmatolepis perlobata postera, Polygnathus granulosus*, *Polygnathus* sp. (Figures 7 and 8). The upper boundary of this zone is marked by the first appearance of *Palmatolepis gracilis manca* (Figure 4).

Originally, *Polygnathus styriacus* was nominated as the zonal marker by Ziegler (1962) due to its wide geographic distribution, later Ziegler and Sandberg (1984, 1990) preferred to use *Palmatolepis perlobata postera* as a zonal indicator to define all zones based on the species of *Palmatolepis.* Recently, some authors redefined *Polygnathus styriacus* zone when *Palmatolepis perlobata postera* is absent. The first appearance of *Polygnathus styriacus* and *Palmatolepis perlobata postera* indicates that this zone corresponds to the Lower *postera* zone of Ziegler and Sandberg (1990), *Polygnathus styriacus* zone of Spalletta et al. (2017) and Hartenfels (2011) (Figure 6).

System	Stage	This Study	Ziegler and Sandberg, 1990 Standard Conodont Zonation	Spalletta et al., 2017 New Global Zonation	Hartenfels, 2011 Conodont Zonation	
Devonian (part)	Famennian (part)	*Bispathodus aculeatus aculeatus*	Middle *expansa*	*Bispathodus aculeatus aculeatus*	*Bispathodus aculeatus aculeatus*	
		Palmatolepis gracilis expansa	Early *expansa*	*Palmatolepis gracilis expansa*	*Bispathodus stabilis stabilis*	
		Palmatolepis gracilis manca	Early-Late *postera*	*Palmatolepis gracilis manca*	*Palmatolepis gracilis manca*	
		Polygnathus styriacus		*Polygnathus styriacus*	*Polygnathus styriacus*	
		Pseudopolygnathus granulosus	*Late trachytera*	*Pseudopolygnathus granulosus*	*Ps. granulosus*	*Trachytera- styriacus* Interregnum
						Palmatolepis gracilis sigmoidalis
						Pseudopolygnathus granulosus

Figure 6. Correlation of conodont zones of the upper Famennian succession in İstanbul, Turkey with the conodont zonations proposed by Ziegler and Sandberg (1990), Hartenfels (2011), and Spalletta et al. (2017).

3.3 *Palmatolepis gracilis manca* zone

The zone is defined by the first appearance of *Palmatolepis gracilis manca*, which is the key subspecies for the base of this zone in the sample 14967 (Figure 4). *Bispathodus stabilis vulgaris* (morphotype 1), *Bispathodus stabilis stabilis* (morphotype 2), *Mehlina strigosa*, *Palmatolepis gracilis sigmoidalis, Palmatolepis gracilis gracilis, Palmatolepis gracilis manca, Palmatolepis minuta schleizia*, *Palmatolepis perlobata postera, Polygnathus granulosus*, *Polygnathus* sp. ranged through this zone (Figures 7 and 8). The upper boundary of this zone is marked by the first appearance of *Palmatolepis gracilis expansa* (Figure 4).

The appearance of *Palmatolepis gracilis manca* indicates that this zone corresponds to the Upper *postera* zone of Ziegler and Sandberg (1990), *Palmatolepis gracilis manca* zones of Spalletta et al. (2017) and Hartenfels (2011) (Figure 6).

3.4 *Palmatolepis gracilis expansa* zone

The entry of the eponymous species *Palmatolepis gracilis expansa* in the sample 12499 allows the discrimination of this zone. The upper boundary of the zone is defined by the first appearance of *Bispathodus aculeatus aculeatus* (Figure 4). The accompanied fauna in the sample 12499 comprises *Bispathodus stabilis vulgaris* (morphotype 1), *Bispathodus stabilis stabilis* (morphotype 2), *Branmehla inornata*, *Icriodus* sp., *Mehlina strigosa*, *Palmatolepis gracilis sigmoidalis, Palmatolepis gracilis gracilis, Palmatolepis gracilis manca, Palmatolepis minuta schleizia*, *Palmatolepis perlobata postera, Polygnathus granulosus*, *Polygnathus experplexus, Polygnathus* sp., *Polygnathus semicostatus* (Figures 7 and 8).

The *Palmatolepis gracilis expansa* zone is coeval with the Lower *expansa* zone of Ziegler and Sandberg (1990), and to the *Palmatolepis gracilis expansa* zone of Spalletta et al. (2017) (Figure 6). Hartenfels (2011) described this zone by the first entry of *Bispathodus stabilis stabilis* (morphotype 2), however, this species recorded in the older units from the other regions so the lower entry of this species cannot be used in the zonation.

3.5 *Bispathodus aculeatus aculeatus* zone

The *Bispathodus aculeatus aculeatus* zone, covering the uppermost part of the studied section between the samples 12501, 12503, 12532, 12533, is established by the first occurrence of the marker, *Bispathodus aculeatus aculeatus*, and by the presence of *Bispathodus jugosus* (Figure 4). The upper boundary of this zone cannot be determined due to the lack of zonally diagnostic species, *Bispathodus costatus*. The abundance and diversity of the conodont fauna are very low in this interval; in addition to the 2 marker species, the conodont fauna includes *Bispathodus stabilis vulgaris* (morphotype 1), *Bispathodus stabilis stabilis* (morphotype 2), *Bispathodus spinulicostatus*, *Mehlina strigosa*, *Branmehla inornata*, *Palmatolepis gracilis sigmoidalis, Palmatolepis gracilis gracilis* (Figures 7 and 8).

The *Bispathodus aculeatus aculeatus* zone in this study can be correlated with the Middle expansa Zone of Ziegler and Sandberg (1990), *Bispathodus aculeatus aculeatus* zone of Spalletta et al. (2017), and Hartenfels (2011) (Figure 6).

4. Conodont biofacies

Upper Devonian conodont biofacies models were proposed and discussed by Sandberg (1976), Sandberg and Ziegler (1979), Sandberg and Dreesen (1984), Dreesen et al. (1986) and Ziegler and Weddige (1999). These studies established nine standard Upper Devonian conodont biofacies belts ranging from deep water to

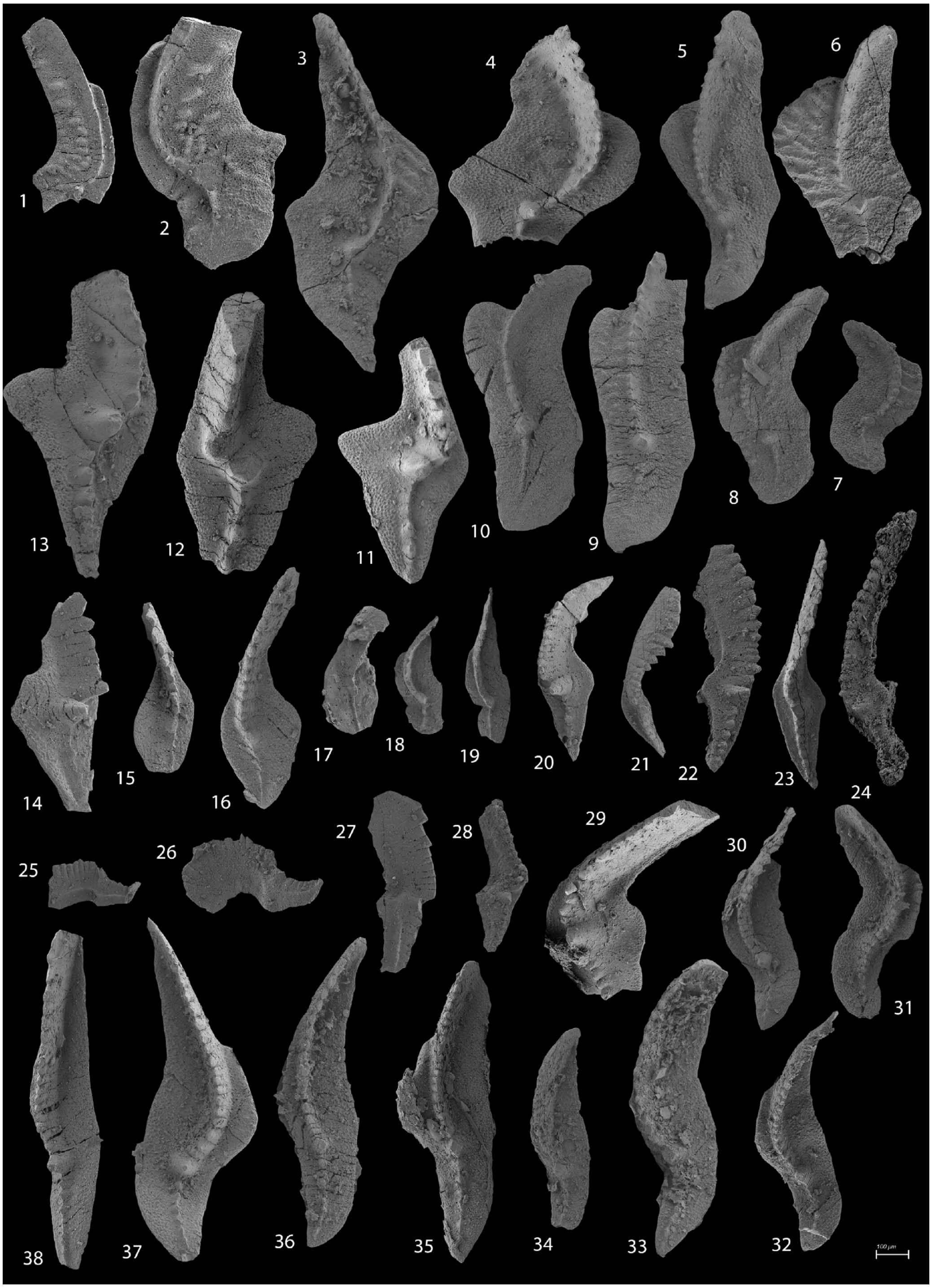

Figure 7. Scanning electron microphotographs of conodonts from İTÜ Campus section. **1-2.** *Palmatolepis rugosa trachytera* Ziegler, 1960, (1: sample 14964; 2: sample 14963), **3-5.** *Palmatolepis perlobata schindewolfi* Müller, 1956 (3: sample 14966; 4: sample 12496; *sample* 12499), **6-8.** *Palmatolepis perlobata postera* Ziegler, 1960 (6, 8: sample 14966; 7: sample 12498), **9-10.** *Palmatolepis perlobata helmsi* Ziegler, 1962 (9: sample 14966; 10: sample 14963), **11-14.** *Palmatolepis minuta schleizia* Helms, 1963, (11, 14: sample 12496; 12: sample 12498; 13: sample 14962), **15-17.** *Palmatolepis minuta minuta* Branson and Mehl, 1934, (15, 17: sample 12496; 16: sample 14961), **18-19.** *Palmatolepis gracilis manca?* Helms, 1963, (sample 14967), **20.** *Palmatolepis gracilis* gracilis? Branson and Mehl, 1934, (sample 12496), **21-24.** *Palmatolepis gracilis* gracilis Branson and Mehl, 1934, (21: sample 14961; 22, 23: sample 12496; 24: sample 12503), **25-28.** *Palmatolepis gracilis sigmoidalis* Ziegler, 1962, (25: sample 14961; 26, 28: sample 12498; 27: sample 12496), **29.** *Palmatolepis gracilis expansa* Sandberg and Ziegler, 1979, (sample 12499). **30-33.** *Palmatolepis glabra distorta* Branson and Mehl, 1934, (30: sample 14962; 31: sample 14961; 32: sample 12496; 33. Sample 14965), **34-38.** *Palmatolepis glabra lepta* (Ziegler & Huddle 1968), (34: sample 14963; 35,38: sample 12496; 36: sample 14962; 37: sample 14961).

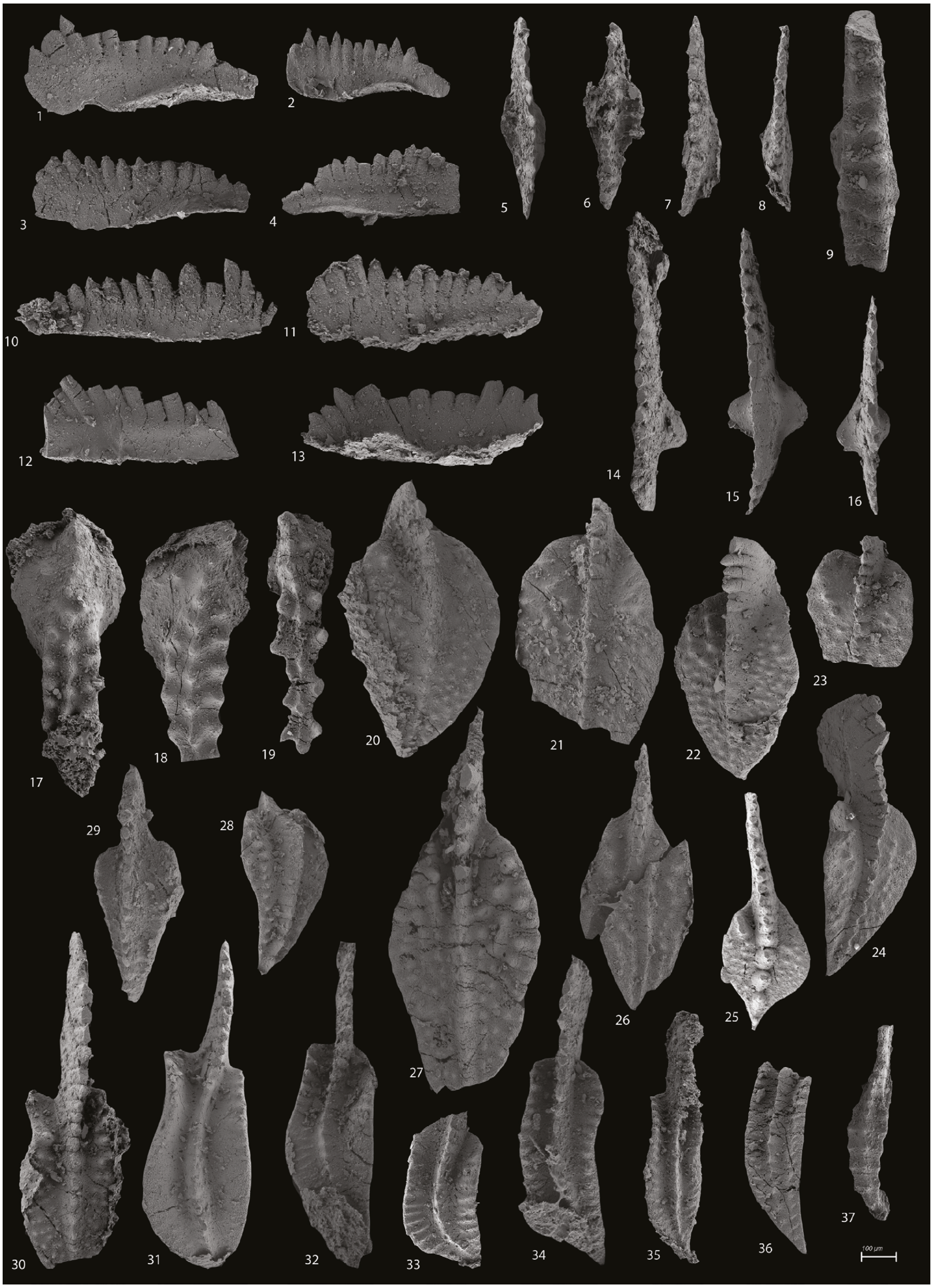

Figure 8. Scanning electron microphotographs of conodonts from İTÜ Campus section. **1-2, 5-6.** *Bispathodus stabilis vulgaris* (Branson & Mehl, 1934) (morphotype 1), (1, 6: sample 12496; 2,5: sample 12499), **3-4, 7,8.** *Bispathodus stabilis stabilis* (Branson & Mehl, 1934) (morphotype 2), (3-4, 8: sample 12496; 7: sample 12498), **9.** *Bispathodus jugosus* (Branson & Mehl, 1934), (sample 12503), **10-11.** *Mehlina strigosa* (Branson & Mehl, 1934), (10: sample 12499; 11: sample 12496), **12-16.** *Branmehla inornata* (Branson & Mehl, 1934), (12-15: sample 12499; 16: sample 12501), **17-19.** *Icriodus* sp., (sample 12499), **20, 22, 24, 25.** *Polygnathus granulosus* Branson & Mehl, 1934 (20: sample 14962; 22: sample 12496; 24: sample 12499; 25: sample 12496), **21, 23.** *Polygnathus* aff. *styriacus* Ziegler, 1957, (21: sample 14967; 23: sample 12498), **26-27.** *Polygnathus* cf. *granulosus* Branson & Mehl, 1934, (26: sample 14967; 27: sample 14966), **28-29.** *Pseudopolygnathus granulosus,* Branson & Mehl, 1934, (sample 14962), **30.** *Polygnathus* cf. *experplexus* Sandberg & Ziegler, 1979 (sample 12499), **31.** *Polygnathus* sp. Huddle, 1934 (sample 14961), **32-33.** *Polygnathus* sp., (32: sample 14962; 33: sample 12496), **34-36.** *Polygnathus semicostatus* Branson & Mehl, 1934, (34: sample 14967; 35,36: sample 12499), **37.** *Alternognathus* sp., (sample 12496).

restricted-marine and peritidal environments based on the abundance of genera *Palmatolepis, Mehlina, Branmehla, Bispathodus, Polygnathus*, and *Icriodus* which are considered to be major markers of paleobasinal depths. The conodont assemblage of the studied Famennian succession of Ayineburnu Formation is predominantly composed of the species of *Palmatolepis, Bispathodus* and *Polygnathus* with only minor contributions of *Icriodus* and *Alternognathus*, and represent offshore palmatolepid-bispathodid biofacies. Palmatolepid and bispathodids, including the species of *Bispathodus*, *Branmehla*, and *Mehlina,* are generally considered as deep-water genera (Sandberg, 1979; Ziegler and Sandberg, 1984), on the other hand, the species of *Icriodus* and *Alternognathus* are characteristic of very shallow water conditions, chiefly inner platform environments and are rarely documented on outer platforms (Sandberg, 1976). Although their presence is representative of shallow water environments, those conodonts can also be found in off-shore and deep-water environments in a very low abundance and diversity (Sandberg and Dreesen, 1984). The palmatolepid-bispathodid biofacies is characteristic of an offshore deep-water depositional setting corresponding to an outer shelf to slope environment. *Palmatolepis* dominates the conodont assemblage of the İTÜ Campus section, its abundance decreases towards the top of the succession concurrently with an increase in the abundance of the genus *Bispathodus*. The conodont fauna in the İTÜ campus section indicates deep marine outer platform depositional conditions during the late Famennian.

5. Discussion and conclusions

The Ayineburnu Formation represents the end of the long-ranging Devonian carbonate deposition in the İstanbul region; it is overlain by the black radiolarian cherts of the Middle-Upper Tournaisian Baltalimanı Formation (Noble et al., 2008). The Ayineburnu Formation, as described from several localities in the İstanbul region, consists of thinly bedded, nodular limestones intercalated with shales and with rare chert beds and nodules (Kaya, 1971; Çapkınoğlu, 1997, 2000, 2005a, 2005b; Göncüoğlu et al. 2004). The lower part of the İTÜ Campus section has a similar lithology although cherts are conspicuously absent; the top part of the İTÜ Campus section consists of thinly bedded siltstones, which are not mentioned in the other measured sections. These siltstones could be equivalent to the sandstones and shales, described by Kaya (1971) under the name of the Küçükyalı member from underneath the radiolarian cherts of the Baltalimanı Formation.

Previous studies on the conodonts from the Ayineburnu Formation showed that its age ranges from the latest Frasnian (lower *rhenana* Zone) to early Tournaisian (*isosticha*- Upper *crenulata* Zone) with most of the intervening conodont zones shown to be present (Çapkınoğlu, 1997, 2000; 2005a, 2005b; Göncüoğlu et al., 2014). Although the thickness of the Ayineburnu Formation is less than 70 m, its deposition ranged for over 20 million years indicating long-ranging condensed deposition. This contrasts with the Lower Carboniferous (Visean) Trakya formation, which was deposited over a similar interval, but has a thickness of over 1500 m.

Conodont elements providing a fine-scale biostratigraphical framework led to the distinction of five biostratigraphic zones, *Pseudopolygnathus granulosus*, *Polygnathus styriacus, Palmatolepis gracilis manca*, *Palmatolepis gracilis expansa*, and *Bispathodus aculeatus aculeatus* in the İTÜ Campus section. These conodont zones can be correlated with the Upper Devonian standard zonation revised by Spalletta et al. (2017).

Within the studied section, the species of *Palmatolepis, Bispathodus* and *Polygnathus* are abundant, and those of *Icriodus* and *Alternognathus* are rare. *Palmatolepis*, *Polygnathus* and *Bispathodus* species are considered to represent a deep-water fauna (Ziegler and Sandberg, 1984). *Icriodus* represents mainly shallow water environments, however, its habitat apparently also ranged into deep-water environments during the Famennian time (Sandberg and Dreesen, 1984; McGhee, 2016). Thus, the conodont fauna from the İTÜ Campus section indicates a deep-water depositional setting in an outer platform or distal shelf during the Famennian.

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