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CONODONT BIOSTRATIGRAPHY OF UPPER DEVONIAN TEPHRA BEARING DEPOSITS IN THE İSTANBUL-ZONGULDAK TERRANE, NW TURKEY: INSIGHTS ON THE KELLWASSER EVENTS

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Abstract. New evidence for a biostratigraphic assessment of the limestone succession comprising K-bentonite levels exposed in the Yılanlı Formation of the Istanbul-Zonguldak Terrane are provided from conodonts at the Gavurpınarı quarry in Bartın area (NW Turkey). The succession depicts a shallow marine, nearshore facies setting that comprises rare and low diversity conodont associations mainly exemplified by the species of *Ctenopolygnathus*, *Icriodus* and *Polygnathus*. Conodont faunas from the lower part of the section are of late Frasnian age, including the taxa *Icriodus subterminus* Youngquist, 1947, *Polygnathus* aff. *xylus* Stauffer, 1940, *Icriodus iowaensis iowaensis* Youngquist & Peterson, 1947 and *Ctenopolygnathus brevilaminus* Branson & Mehl, 1934, and the upper part is assigned to early Famennian marked by the first appearance of *Icriodus cornutus* Sannemann, 1955. The local biostratigraphic framework of the Yılanlı Formation is correlated with the upper Frasnian Lower *rhenana* to the lower Famennian Middle *triangularis* standard conodont zonations. Considering the described species, the Frasnian-Famennian boundary corresponds to a slight change in conodont fauna and is assigned within the local *Icriodus iowaensis iowaensis* Zone. Accordingly, the novel K-bentonite age data potentially indicates the evidence for the Kellwasser events in northern Turkey, improving paleogeographic correlations of the Istanbul-Zonguldak Terrane with other terranes in Laurasia and Peri-Gondwana.

Introduction

Late Devonian was marked by worldwide drastic faunal turnovers and major extinctions known as Kellwasser events across the Frasnian-Famennian boundary (Fig. 1a). The possible causes for these extinctions are still a matter of debate addressing extraterrestrial impacts, volcanism, climate changes, such as Milankovitch cyclicity, rapid warming and cooling pulses, eustatic sea-level change, and marine anoxia (e.g., Becker & House 1994; Buggisch 1972; Carmichael et al. 2014; De Vleeschouwer et al. 2017; Du et al. 2008; Isozaki 2019; Joachimski & Buggisch 1993, 2002; Ma et al. 2022; McGhee Jr 2001; Racki 2021; Racki et al. 2018; Sandberg et al. 2002; Schindler 1990; Streel et al. 2000; Wichern et

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al. 2024; Winter 2015; Zhang et al. 2021). Documented worldwide mercury (Hg) enrichments and bentonite (tephra) beds in Upper Devonian deposits imply volcanism as the most probable trigger of the Frasnian-Famennian biotic crisis (e.g., Racki et al. 2018; Winter 2015; Zhang et al. 2021). The significance of K-bentonites has been discussed by various researchers: K-bentonites may be regional marker horizons employed for long-distance stratigraphic correlations of significant volcanic eruptions, possibly controlling climatic changes as well as biological mass extinctions (Huff 2016; Keller 2005; Ver Straeten 2007). Winter (2015) indicated that the Frasnian and lower Famennian marine sediments in Central Europe embrace several thin metabentonite layers, which are the products of alkaline volcanism during the Kellwasser events.

A set of K-bentonite layers has recently been discovered in the Upper Devonian-lower Carboniferous Yılanlı Formation exposed around Zonguldak and Bartın in the Northwestern Black Sea region of Turkey (Türkmenoğlu 2001; Türkmenoğlu et al. 2009). K-bentonites from different levels in the Yılanlı Formation were chemically attributed to basaltic and trachytic ash compositions (Bozkaya et al. 2016; Göncüoğlu et al. 2016; Günal Türkmenoğlu et al. 2012; Günal-Türkmenoğlu et al. 2015). Based on foraminiferal assemblages, the age of Yılanlı Formation is attributed to a broad range, spanning from Late Devonian to Early Carboniferous (Dil 1976; Göncüoğlu et al. 2016). This study presents the first conodont biostratigraphic assessment of the K-bentonite bearing succession from the Gavurpınarı quarry (Bartın) in northwestern Turkey, providing constraints on the depositional age of the parent tephra. The obtained age documents for the first time the Frasnian-Famennian transition in northern Turkey.

Geology

K-bentonite layers within the limestone and dolomitic limestone successions of the Yılanlı Formation are located in the Bartın-Zonguldak area (Fig. 1). The formation represents an Upper Devonian - Lower Carboniferous carbonate platform (e.g., Dil 1976; Boncheva et al. 2009) within the Istanbul-Zonguldak Terrane that extends from the Bosphorus to the Central Pontides in NW Anatolia (e.g. Göncüoğlu, Dirik & Kozlu 1997). The Istanbul-Zonguldak Terrane includes a Palaeozoic succession (Bozkaya et al. 2012; Göncüoğlu & Kozlu 2000; Yanev et al. 2006) overlying an Ediacaran crystalline basement intruded by Cadomian arc-type granitioids (Göncüoğlu et al. 2022). This basement is unconformably overlain by Lower Ordovician Bakacak Formation composed of graptolite bearing greenish grey siltstones and mudstones (Derman 1997; Göncüoğlu et al. 2014). They are followed by Lower - Middle Ordovician Kurtköy and Aydos formations including red-pink shallow marine conglomerates and quartz-arenites. The overlying thick Upper Ordovician to middle Silurian package includes the Karadere and the Ketencikdere formations with graptolite-bearing black and grey shales and siltstones with limestone interlayers (Dean et al. 1997). The upper Silurian strata were eroded, and the Fındıklı Formation unconformably overlies the middle Silurian rocks and is overlain by the Middle Devonian Ferizli Formation (Yılmaz et al. 2015). The upper part of the Fındıklı Formation is characterized by alternating red and green mudstones and sandstones at the bottom, followed by a series of dolostones, dolomitic limestones with oolitic ironstones, and chamositic mudstones at the top. Conodonts from these carbonates indicate the *delta–pesavis* zones of the late Lochkovian (Yılmaz et al. 2015). The Ferizli Formation unconformably overlies the Fındıklı Formation with a quartz-arenite succession at the bottom. The Ferizli Formation comprises alternating red, iron-rich limestones and dolomitic limestones, with a prevalence of iron-rich bioclastic grainstones facies. Conodont associations of dolomitic limestones in this succession mark the *ensensis* and *hemiansatus* zones of upper Eifelian into Givetian (Boncheva et al. 2009). Moreover, middle Givetian age (*varcus-hermanni* zones) is also reported for this unit (Yılmaz et al. 2015). Upwards, the Ferizli Formation is transitional to the Upper Devonian - Lower Carboniferous Yılanlı Formation consisting of gray, dark gray, and black medium- to thick-bedded limestones, dolomitic limestones, and dolomites alternating with thin-bedded, black, and green calcareous shales (Saner et al. 1980; Boncheva et al. 2009). Previous biostratigraphic data (Dil 1976) initially suggested an Eifelian-Visean depositional age for the Yılanlı Formation: more recent studies proposed that this formation was deposited during Late Devonian - Early Carboniferous

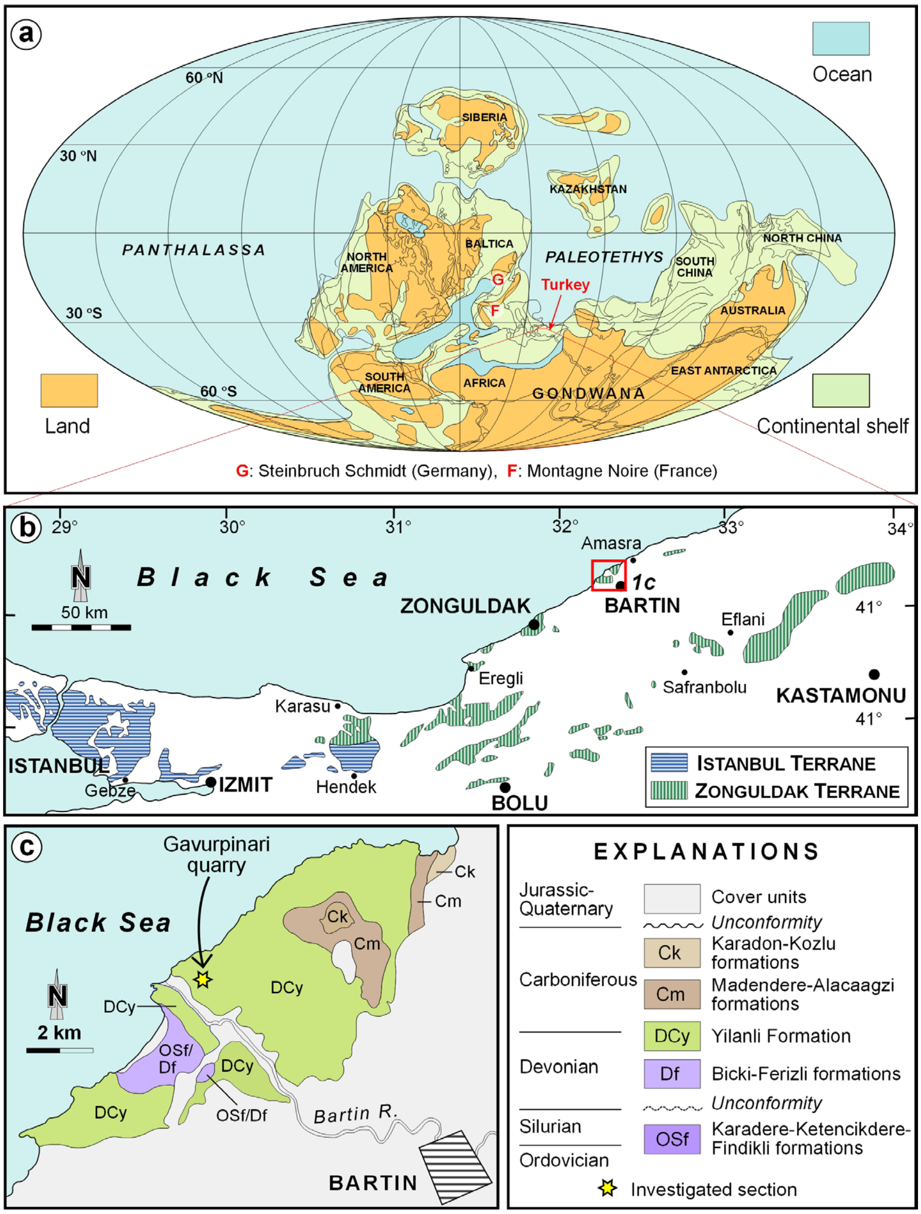

Fig. 1 - a) Late Devonian palaeogeography (modified after Joachimski et al. 2009 and Huang et al. 2018a) and the locations of Frasnian-Famennian boundary GSSP at the Upper Coumiac Quarry, Montagne Noire, France (Klapper et al. 1994) and the Frasnian-Famennian succession with bentonite bed at the Steinbruch Schmidt Quarry, Germany (Percival et al. 2018); b) distribution of Paleozoic rock units in the Istanbul and Zonguldak terranes, NW Turkey; c) geological map of the study area (MTA 2002) and the location of the studied section.

(Boncheva et al. 2009; Yılmaz et al. 2015). Yalçın and Yılmaz (2010) assume that the formation was deposited in an epeiric carbonate platform/shelf that was covering vast areas in northern Gondwana during this time interval (Harries 2009; Kabanov et al. 2010). The formation is conformably overlain by a sequence of alternating limestones and shales (Madendere and Karadon formations), followed by flood-plain deposits with numerous coal seams of Westphalian age (Kerey 1984).

The studied succession with K-bentonite beds is found in the upper part of the Yılanlı Formation in the Zonguldak Unit to the north of Bartın city (Fig. 1). The most complete outcrop is located in the Gavurpınarı limestone quarry (coordinates: 41°42'04.39'N, 32°1'41.88') embracing well-exposed verticalized continuous succession of about 40 m thick. The studied succession is bounded to the north by a normal fault within the Yılanlı Formation, where the measured section starts. Towards the south, the section comprises massive and thick-bedded, grey–grey brown limestones and dolomitic limestones. They are interbedded with nine blue-green K-bentonite beds, from 2 to 60 cm thick. Because of weathering, they are yellowish-brown in color, due to oxy-hydroxidization of pyrites. Limestones and dolomitic limestones intercalating with these K-bentonite beds are poor in fossils. Only a few samples have yielded foraminiferal assemblages marking a relative age range from Late Devonian to Carboniferous, including the species of *Eogeinitzina,* a significant Frasnian genus allowing mainly global

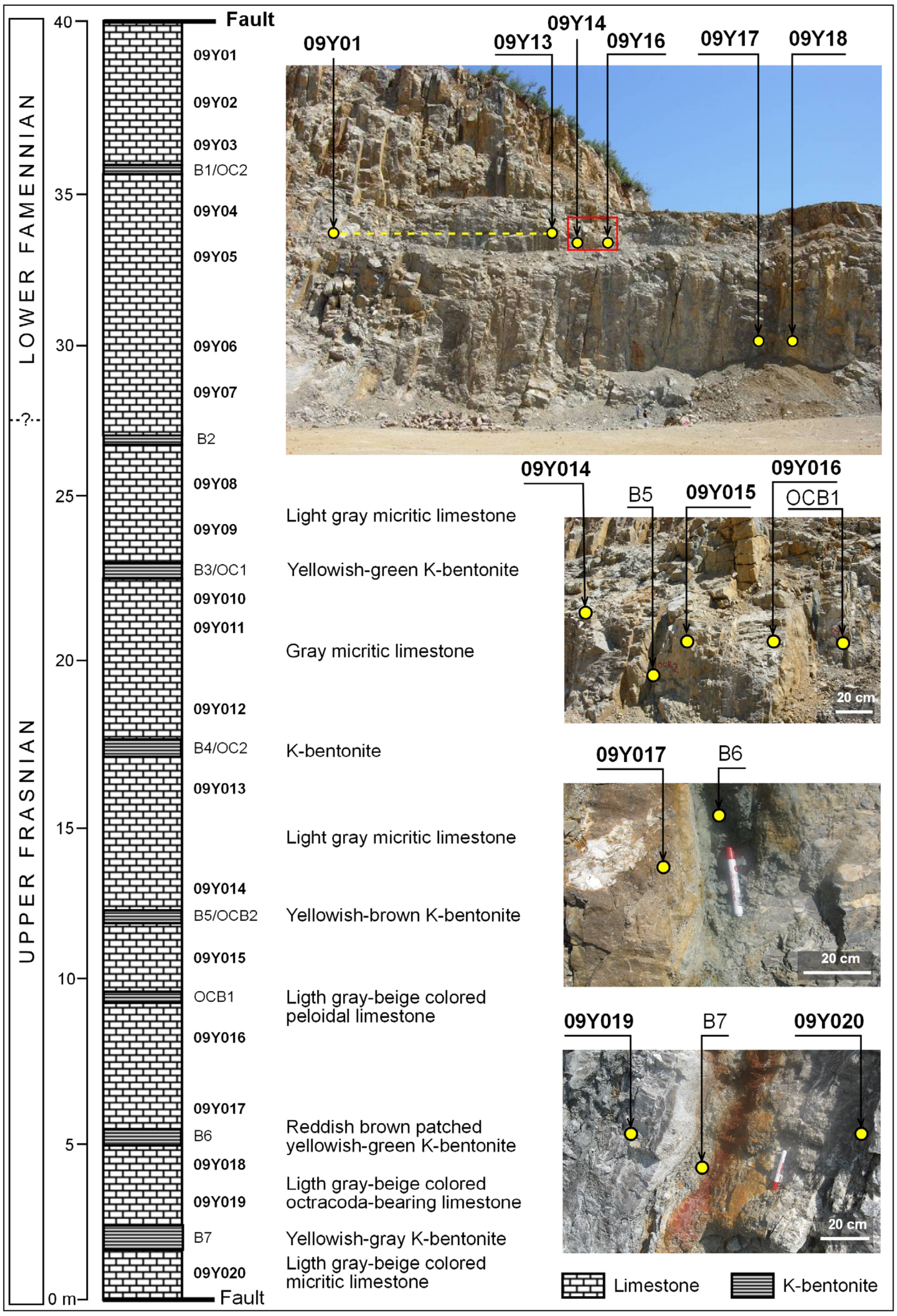

Fig. 2 - Stratigraphic distribution, field appearance, and locations of limestone and K-bentonite samples in the Gavurpınarı limestone quarry (modified by Günal-Türkmenoğlu et al. 2015).

correlation of upper Frasnian carbonate deposits (Göncüoğlu et al. 2016).

Conodont biostratigraphy

Upper Devonian conodont zonation constructed by Ziegler & Sandberg (1990) is mainly based on the offshore pelagic palmatolepids, which are rare or absent in shallow water deposits. Therefore, in nearshore deposits, nine icriodontid zones employed by Sandberg & Dreesen (1984) are used. Later modifications for Upper Devonian zonation have been proposed by Corradini (2008), Hartenfels (2011), Kaiser et al. (2009), Klapper & Kirchgasser (2016) and Spalletta et al. (2017). In this study, the established local conodont zonation is roughly correlated with the standard conodont zonation of Ziegler & Sandberg (1990), Frasnian zonation of Klapper & Kirchgasser (2016) initially proposed by Klapper (1989), and Famennian zones based on the Spalletta et al. (2017).

Conodonts are not abundant within the studied section in Gavurpınarı quarry (Bartın): only a few samples yielded elements in the studied shallow neritic succession. Conodont associations within

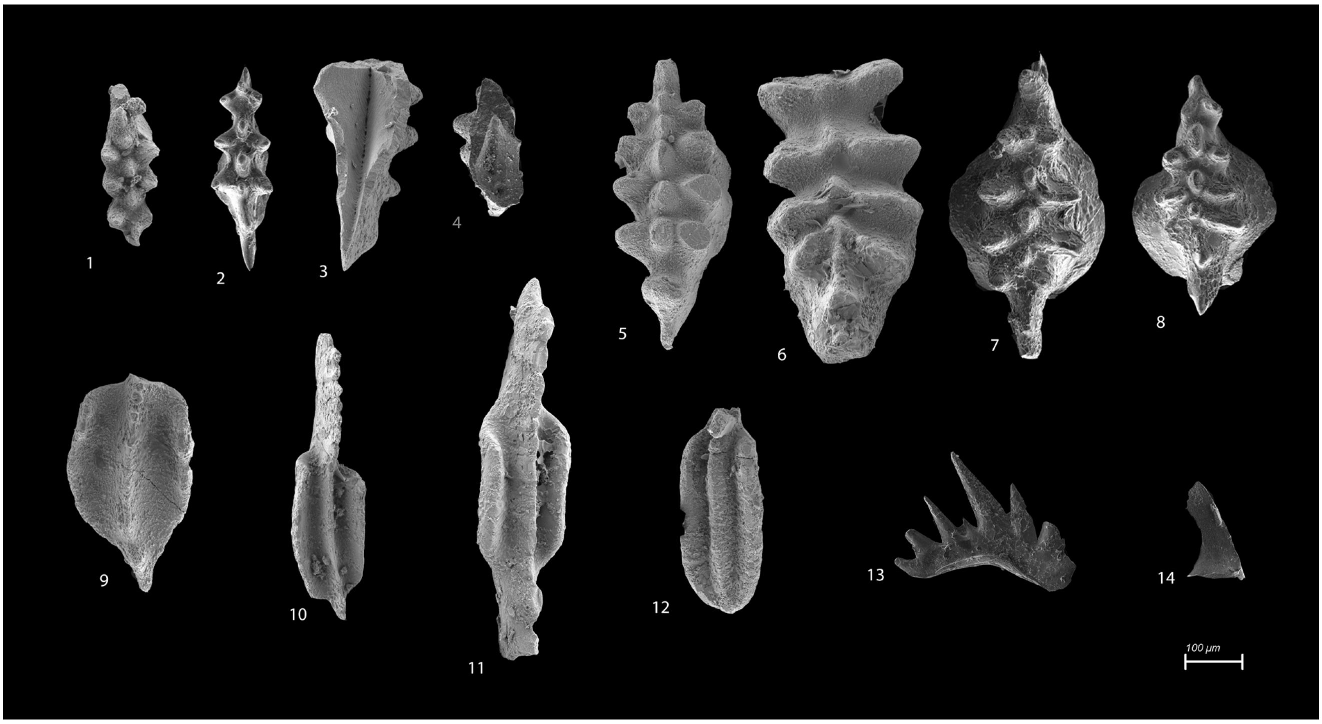

Fig. 3 - Scanning electron microphotographs of conodonts from the studied section at the Gavurpınarı quarry in Bartın, Northwestern Turkey. 1-4) *Icriodus cornutus* Sannemann, 1955 (Sample 09Y03), 5) *Icriodus* sp. (Sample 09Y09), 6) *Icriodus iowaensis iowaensis* Youngquist & Peterson, 1947 (Sample 09Y09), 7-8) *Icriodus subterminus* s.l. Youngquist, 1947 (Sample 09Y20), 9) *Polygnathus* sp. (Sample 09Y01), 10-11) *Ctenopolygnathus brevilaminus* s.l. Branson & Mehl, 1934 (Sample 09Y13), 12) *Polygnathus* aff. *xylus* Stauffer, 1940 (Sample 09Y20), 13) P2 element (Sample 09Y03), 14) S element of *Icriodus* (Sample 09Y03).

the studied section are mainly represented by shallow water species of the genera *Ctenopolygnathus, Icriodus* and *Polygnathus* characterized by low diversity and low abundance during late Frasnian and early Famennian (Figs. 3, 4). Although no biostratigraphically diagnostic *Palmatolepis* specimens have been found within the sequence, four biostratigraphic intervals have been recognized in the Gavurpınarı quarry (Fig. 4). The base of the studied section starts with the *Icriodus subterminus* s.l. - *Polygnathus* aff. *xylus* assemblage Zone. The lowermost part of the section is particularly poor in conodonts and contains rare representatives of *Icriodus subterminus* s.l. Youngquist, 1947 and *Polygnathus* aff. *xylus* Stauffer, 1940 (Fig. 4). The *Icriodus subterminus* Youngquist, 1947 has been mainly known from the late Givetian to the late Frasnian. Narkiewicz & Bultynck (2010) discriminated two morphotypes of this species based on differences in the development of denticles within the posterior extension of the middle row. According to this study, the stratigraphic range of alpha morphotype extends to the top of the MN 3 Zone (lower Frasnian), and beta morphotype range into the MN 6 Zone (middle Frasnian). Furthermore, the stratigraphic distribution of *Icriodus subterminus* Youngquist, 1947 reveals variability, with documented occurrences in the middle and upper Frasnian (e.g., Day & Witzke 2017; Klapper 1997; Klapper & Lane 1985). Gholamalian & Kebriaei (2008), Matyja (1993) and Ziegler & Sandberg (1990) extend the occurences of *Icriodus subterminus* Youngquist, 1947 into the Lower *rhenana* zone. In some studies (e.g., Ji 1989; Rodygin 2015), this species has been recorded in basal Famennian. In our study, *Icriodus subterminus* s.l. Youngquist, 1947 has been identified in the lowermost part of the studied section together with *Polygnathus* aff. *xylus* Stauffer, 1940. The occurrences of these species are an important indicator of late Frasnian age; hence, this local zone can be correlated with the Lower *rhenana* zone of standard conodont zonation of pelagic facies proposed by Ziegler & Sandberg (1990) (Fig. 5). The *Ctenopolygnathus brevilaminus* s.l. zone within the section is defined by the disappearance of *Icriodus subterminus* s.l. Youngquist, 1947 and *Polygnathus* aff. *xylus* Stauffer, 1940 (Fig. 4). This assemblage is characterized by the occurrences of *Ctenopolygnathus brevilaminus* not associated with *Palmatolepis*. *Ctenopo-*

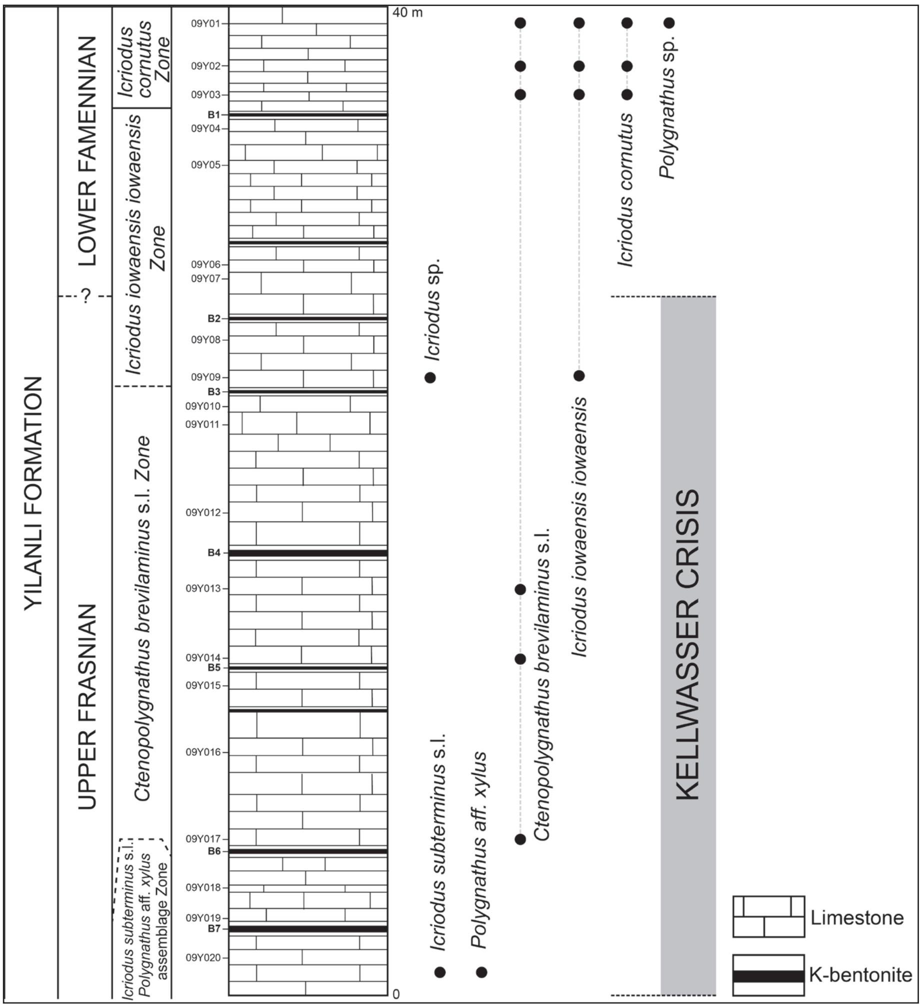

Fig. 4 - Stratigraphic distribution of conodont species and the upper Frasnian – lower Famennian conodont zonation across the studied section at the Gavurpınarı quarry in Bartın, Northwestern Turkey.

lygnathus brevilaminus s.l. appears for the first time at the base of this zone. Classification of *Ctenopolygnathus* species, primarily characterized by its posteriorly free carina, has been challenging due to the lack of clear distinctions in the literature and the wide range of variabilities in morphotypes. *Ctenopolygnathus angustidiscus* lacks distinctive ornamentations on the platform margin and has a very short platform and long posterior free blade. Similarly, *Ctenopolygnathus brevilaminus* Branson & Mehl, 1934 has also short platform, and but this species bears asymmetrically elevated lateral margins with distinctive ornamentations. *Ctenopolygnathus parallelus* characterized by rectangular smooth platform and equally elevated lateral margins parallel to median ridge. The specimens described within the studied section display considerable variations, featuring weakly ornamented or unornamented rectangular platforms with asymmetrically elevated lateral margins and a long posterior free blade. These species share similarities with *Ctenopolygnathus parallelus* and *Ctenopolygnathus angustidiscus* in terms of having a rectangular platform featuring subtle ornamentations but distinguishes through asymmetrically elevated lateral platform margins and long posterior free blade. Ziegler & Sandberg (1990) and Bahrami et al. (2013) documented the lowest occurrence of *Ctenopolygnathus brevilaminus* Branson & Mehl, 1934 in Lower *rhenana* zone. However, in many studies, it is mostly reported in Upper *rhenana* zone (e.g. Huang et al. 2018b; Huang & Gong 2016; Wang & Geldsetzer 1995) and *linguiformis* zone (e.g., (Cheng-Yuan & Ziegler 2002; Cui et al. 2021; Ta et al. 2022; Tagarieva 2013; Woroncowa-Marcinowska 2006). Overlying samples yielded conodont species useful for zonal identification, corresponding to *Icriodus iowaensis iowaensis* Zone. The upper boundary of this local biozone is designated by the appearance of *Icriodus cornutus* Sannemann, 1955 (Fig. 4). *Icriodus iowaensis iowaensis* Youngquist & Peterson, 1947 has been formerly considered to have evolved at Middle *triangularis* Zone (Ji & Ziegler 1993). It was also thought to have evolved in Lower *triangularis* Zone (Huang et al. 2018b; Huang & Gong 2016; Sandberg & Dreesen 1984). However, it occurs not only

Fig. 5 - Correlation of conodont zones of the Frasnian-Famennian boundary succession in Bartın, Turkey with the conodont zonations proposed by Sandberg & Dreesen (1984), Ziegler & Sandberg (1990), Klapper & Kirchgasser (2016), Spalletta et al. (2017) and Becker et al. (2020).

	Ziegler & Sandberg 1990		Becker et al. 2020 Spalletta et al. 2017 Klapper&Kirchgasser 2016			Sandberg & Dreesen 1984	Local Conodont Zonation This paper
Lower Famennian	*triangularis*	Middle	*Palmatolepis delicatula platys*			*Icriodus cornutus*	*Icriodus cornutus*
		Lower	*Palmatolepis triangularis*			*Pelekysgnathus planus*	*Icriodus iowaensis iowaensis*
			Palmatolepis subperlobata				
Upper Frasnian	*linguiformis*		MN 13	c	*Pa. ultimata*		*Ctenopolygnathus brevilaminus* s.l.
				b	*Pa. linguiformis*		
	rhenana	Upper		a	*Pa. bogartensis*		
		Lower	MN 12		*Pa. winchelli*		*Icriodus subterminus* s.l. *Ctenopolygnathus* aff. *xylus* assemblage

in *triangularis* Zones, but also during *linguiformis* Zone (e.g., Bahrami et al. 2013; Bultynck 2003; Lazreq 1999; Morrow 2000; Schülke 1998a; Tagarieva 2013). However, the occurrence of early forms reported in Upper *rhenana* Zone (e.g., Sandberg et al. 1992; Wang & Geldsetzer 1995; Ziegler & Sandberg 1990) and even in Lower *rhenana* Zone (Bahrami et al. 2013). Though no marker species were documented within this interval, local *Ctenopolygnathus brevilaminus s.l.* and *Icriodus iowaensis iowaensis* zones are thought to be closely correlated with the Upper *rhenana* - *linguiformis* - Lower *triangularis* zone interval of standard conodont zonation by Ziegler & Sandberg (1990). Furthermore, the lower part of this interval can be correlated with MN13 of Klapper & Kirchgasser (2016), while the upper part is more likely comparable to MN12 of Klapper & Kirchgasser (2016) and the *Palmatolepis subperlobata* – *Palmatolepis triangularis* zones as defined by Spalletta et al. (2017) (Fig. 5). It is difficult to identify Lower *triangularis* zone due to scarcity of diagnostic species in the studied samples. The youngest *Icriodus cornutus* Zone is defined in the upper part of the studied section by the first occurrence of eponymous species, which has its first appearance datum at the base of Middle *triangularis* zone (Figs. 4, 5). Other important conodonts within this zone are *Ctenopolygnathus brevilaminus s.l.* Branson & Mehl, 1934, *Polygnathus* sp., *Icriodus* sp., *Icriodus iowaensis iowaensis* Youngquist & Peterson, 1947. *Icriodus cornutus* Sannemann, 1955 appears in a level no lower than the Middle *triangularis* Zone according to the records from Europe and South China (e.g., Huang et al. 2018b; Matyja 1993; Sandberg & Dreesen 1984). Therefore, this zone is equivalent to Middle *triangularis* zone defined by Ziegler and Sandberg (1990), *Palmatolepis delicatula platys* zone of Spalletta et al. (2017) and lower *"Icriodus" cornutus* zone proposed by Sandberg & Dreesen (1984) for nearshore conodont zonation (Fig. 5).

Discussion on the Frasnian-Famennian boundary

The Frasnian-Famennian boundary, characterized by one of the most severe mass extinction events of the Phanerozoic, was initially placed at the base of Middle *triangularis* Zone (Ziegler & Klapper 1985) and then moved down to the base of Lower *triangularis* Zone where the prominent changes in the conodont fauna were documented (e.g., Sandberg et al. 1988). It was recognized that biotic crisis for many invertebrate fossil groups occurred in latest Frasnian (McLaren 1982) and similarly the gradual decrease in conodont diversity specified within late Frasnian due to the Kellwasser events (e.g., Girard & Feist 1996; Girard & Renaud 2007). Subsequently, lower Famennian have been assigned to the recovery interval (Wang & Ziegler 2002; Sandberg et al. 1988; Schülke 1998; Zhuravlev & Sokiran 2020; Ziegler & Lane 1987). The Frasnian-Famennian boundary has been formerly established by the first occurrence of *Palmatolepis triangularis* (Ziegler & Sandberg 1990). Though, concerning taxonomic problems associated with this species (House et al. 2000; Klapper et al. 1994; Schindler et al. 1998; Schülke 1997, 1999), it has been noted that the boundary does not coincide with the first appearance of *Palmatolepis triangularis* (Becker et al. 2020). Klapper et al. (2004) redefined Lower *triangularis* Zone by the abundant occurrence of *Palmatolepis ultima* directly above the sudden extinction of the dominant Frasnian conodont species. Later, this zone was also delineated by the first occurrence of *Palmatolepis subperlobata* (Klapper 2007). Furthermore, the validity of this definition has been accepted by many studies (e.g., Becker et al. 2020; Klapper 2007; Klapper & Kirchgasser 2016; Spalletta et al. 2017). *Palmatolepis* is commonly recognized as the dominant taxon in deep water environments whereas *Icriodus* is predominantly considered for its affinity towards shallow water habitats (Sandberg et al. 1988; Sandberg 1976; Seddon & Sweet 1971); however, some species of *Icriodus* have been documented in deeper settings (Corradini 1998; Lüddecke et al. 2017). The studied succession was deposited in a shallow marine, nearshore setting, with a scarce conodont record generally characterized by *Ctenopolygnathus, Icriodus* and *Polygnathus* without *Palmatolepis*. Based on the local conodont biostratigraphy, the studied succession, which shows no evidence of any hiatus, was deposited during late Frasnian - early Famenian time interval, thus preserving the Frasnian-Famennian boundary. The lower part of the section comprises conodonts *Icriodus subterminus* s.l. Youngquist, 1947 and *Polygnathus* aff. *xylus* Stauffer, 1940, important indicators of late Frasnian age. *Ctenopolygnathus brevilaminus* Branson & Mehl, 1934 and *Icriodus iowaensis iowaensis* Youngquist & Peterson, 1947 have been found in the upper part of Frasnian and cross the Frasnian-Famennian boundary. In the uppermost part of the studied section, conodont *Icriodus cornutus* Sannemann, 1955 appears successively, indicating lower Famennian Middle *triangularis* zone. Based on the established conodont succession and its correlation with the pelagic standard conodont zonation and other alternative zonations, Frasnian-Famennian boundary in the Yılanlı Formation cannot be precisely determined due to the absence of marker species. The boundary is tentatively located within *Icriodus iowaensis iowaensis* local zone (Fig. 5).

Late Frasnian - early Famennian time interval includes the Kellwasser crisis characterized by deposition of black shales and bituminous limestones marking two pulses of anoxic events (Schindler 1990) identified as Lower and Upper Kellwasser events. Based on the standard conodont zonation, the Lower Kellwasser Event is within the Upper *rhenana* Zone (at the FZ 12- FZ13 transition) and the Upper Kellwasser Event occurred during the latest Frasnian *linguiformis* Zone (at the top of FZ 13). Black shales or bituminous limestones related to the Kellwasser events are documented in deep water shelf and basinal paleoenvironments, whilst they are only rarely recorded in shallow-water settings (Bond et al. 2013; Carmichael et al. 2014, 2019). Consequently, alternative evidence of this event has been identified (Bond et al. 2013). Very thin metabentonite layers intercalated in marine sediments of the Frasnian and lower Famennian in Central Europe (Winter 2015) are interpreted as the effect of intensified volcanism during the Kellwasser crisis: this is also observed in upper Frasnian and lower Famennian limestone successions of the Istanbul-Zonguldak Terrane in the Bartın region (Turkey), where K-bentonites formed by alteration of volcanic ash or tephra testifying for significant volcanic eruptions. Accordingly, these volcanic events are potential regional marker horizons, which can be employed for long-distance stratigraphic correlations of the effects of significant volcanic eruptions, considered to be the cause of climatic changes and biological mass extinctions (Ager 1973; Ballo et al. 2019; Christidis & Huff 2009; Claoué-Long et al. 1991; Droste & Vitaliano 1973; Keller 2005; Rakociński et al. 2021; Ver Straeten 2007).

Within the studied succession typical prominent black shale deposits of the Kellwasser events cannot be documented, due to deposition in shallow-water settings. K-bentonite layers within limestone beds may be related to the Kellwasser crisis around the Frasnian-Famennian boundary in northern Turkey. This biostratigraphic constraint of the K-bentonite intervals could potentially document the recording of the Kellwasser events in the region.

Conclusion

Conodonts are important biostratigraphic tools for the calibration and definitions of stage boundaries within Devonian. Particularly, the Late Devonian subdivisions are mainly defined by pelagic palmatolepids, but shallow water icriodontids and polygnathids can also be used for dating and correlation, although with lower precision. The studied succession of the Gavurpınary quarry in the Istanbul-Zonguldak Terrane in Bartın (northwestern Turkey), although not particularly rich in conodonts, provides interesting new data on conodont biostratigraphy at the Frasnian-Famennian boundary. This study, focusing on the biostratigraphic dating of K-bentonite levels within limestones deposited across the Frasnian-Famennian boundary provides a preliminary assessment of local conodont biostratigraphy and its correlation with global scales. It can serve as a base for further detailed sedimentological, paleontological, and palaeogeographic studies.

Conodont faunas are essentially represented by *Ctenopolygnathus, Icriodus* and *Polygnathus,* which are common in shallow water platform environments. Conodont specimens enable the definition of a local zonation. Based on the first and last occurrences of these species, four local biozones have been established at the Gavurpınarı quarry. Upper Devonian standard conodont zonation sensu Ziegler & Sandberg (1990) and Frasnian zonation of Klapper (1989) and Klapper & Kirchgasser (2016) cannot be applied to the studied section due to the absence of zonal markers. However, local conodont biozonation can be roughly correlated with these zonations by the presence of important associated conodont species.

Conodont data suggest that the studied succession was deposited during the late Frasnian to early Famennian time interval. Due to the lack of index fauna it is challenging to confidently identify the Frasnian-Famennian boundary. This boundary is roughly situated within the *Icriodus iowaensis iowaensis* Zone. The existence of K-bentonite levels in the Yılanlı Formation at the Gavurpınarı quarry of northwestern Turkey probably relates to the Kellwasser crisis, despite not associated with black shales.

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