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FIRST DISCOVERY OF MIDDLE TOURNAISIAN CONODONTS IN THE GRIOTTE-TYPE NODULAR PELAGIC LIMESTONES, ISTANBUL AREA, NW TURKEY

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Abstract. The uppermost layers of the Ayineburnu member of the Büyükada Formation in the Istanbul-Gebze area are represented by Griotte-type pelagic nodular limestones. They yielded conodont elements (*Bispathodus stabilis* and *Siphonodella lobata*) that can identify the interval from the upper part of the *sandbergi* Zone through the *isosticha*- Upper *crenulata* Zone - middle Tournaisian - Early Carboniferous. This is the first middle Tournaisian conodont record published from an autochthonous succession in the Istanbul Terrane, NW Turkey. This level characterizes the very last carbonate deposition and is followed by lydites and black siliceous shales and finally by the accumulation of flysch-type deposits during the late Tournaisian and early Visean, that mark the onset of Variscan events to the north of the Istanbul Terrane. A correlation with the Lower Carboniferous successions in the easterly-located Zonguldak area suggests that Istanbul and Zonguldak terranes were in quite different palaeogeographic positions during this time interval.

Riassunto. Gli strati sommitali del membro Ayineburnu della Formazione Büyükada nell'area di Istanbul-Gebze sono costituiti da calcari pelagici nodulari in facies "griotte". Essi hanno fornito elementi di conodonti (*Bispathodus stabilis* e *Siphonodella lobata*) che possono indentificare l'intervallo cronologico tra la parte superiore della Zona a *sandbergi*, la Zona a *isosticha* sino alla Zona *crenulata* superiore del Tournesiano medio (Carbonifero inferiore). Questo è il primo rinvenimento pubblicato di conodonti del Tournesiano medio nella successione autoctona dell'Istanbul Terrane, Turchia Nord-occidentale. Questo livello caratterizza l'ultimissima deposizione carbonatica ed è seguito da liditi e argilliti silicee nere, cui succedono depositi di tipo flyschoide durante il Turnesiano superiore e Viseano inferiore, denotando così lo svilupparsi degli eventi varisici a nord dell'Istanbul Terrane. Il confronto con le successioni del Carbonifero inferiore di Zonguldak, poste più ad est, indica che i Terranes Istanbul e Zonguldak si trovavano in posizioni paleogeografiche molto differenti durante questo intervallo di tempo.

Introduction

The Palaeozoic rock-units cropping out in Istanbul and surrounding areas are classically known as the "Palaeozoic of Istanbul" and were incorporated in the Istanbul Nappe of Sengör et al. (1984) or the Istanbul Unit of Okay (1989). The unit is assumed to cover the area between the western Bosphorus and Cide bounded to the south by the strands of the North Anatolian Fault Zone (Fig. 1). The stratigraphy of the Palaeozoic formations in this unit has been subject of numerous studies since the 1860s. Paeckelmann (1938) carried out the first detailed stratigraphic work in Istanbul and the Kocaeli Peninsula; this work was followed by a series of comprehensive studies (see Haas 1968 for a review of the previous studies), Kaya (1973 and the contributions therein) and has recently been reviewed by Görür et al. (1997).

The Istanbul Unit consists of a Cadomian crystalline basement with oceanic and island arc-type rocks (e.g. Göncüoglu et al. 1997; Ustaömer 1999), unconformably overlain by a Palaeozoic sequence, extending without any major depositional breaks from Early Ordovician to Late Carboniferous time (e.g. Abdüsselamoglu 1963, 1977). Sengör et al. (1984) suggested that within this unit the Ordovician-Early Silurian period is characterized by "graben-facies" deposits followed by Atlantic-type continental margin sediments of Late Silurian-Late Devonian age. It is widely accepted that the "Istanbul Nappe" was part of the eastern European "Variscan chain" (Görür et al. 1997). During the Cretaceous it was rifted from the Moesian platform, drifted south and collided with the Cimmerides (Okay et al. 1994) during the Early Eocene.

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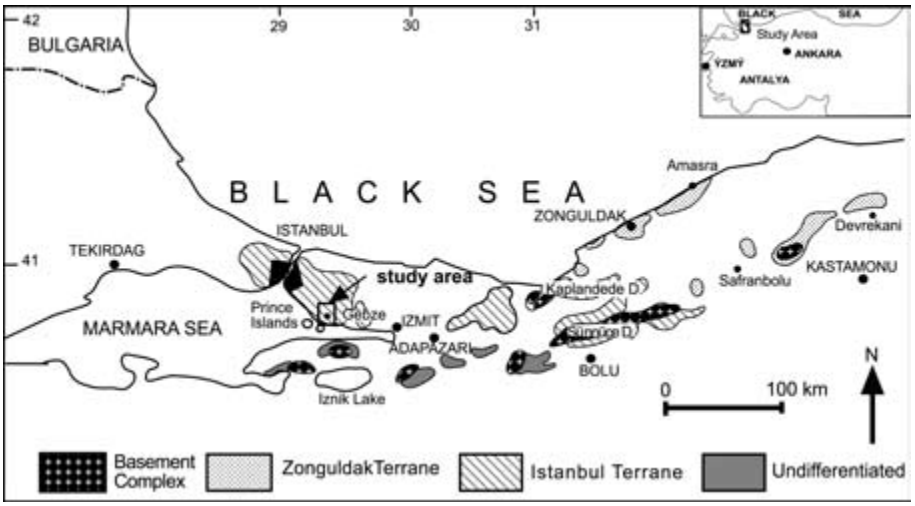

Fig. 1 - Distribution of the Istanbul and Zonguldak terranes in NW Anatolia and the location of the studied succession (simplified after Göncüoglu 2001).

Both studies suggested that this unit remained a part of the Laurasian margin throughout its geological history until its detachment from Moesia in the Late Cretaceous.

Based on new stratigraphic results and a careful review of the previous data in the area between Istanbul and Cide, Göncüoglu (1997) and Göncüoglu & Kozur (1998, 1999) have shown that there are considerable differences in the stratigraphy of the eastern and western parts of the "Istanbul Nappe" of Sengör et al. (1984). Göncüoglu & Kozur (1998, 1999) suggested that the "Istanbul Nappe" actually includes two different Early Palaeozoic terranes: "Istanbul Terrane" in the west and the "Zonguldak Terrane" in the east. In contrast with the suggestions of Sengör (1984) and Görür et al. (1997), Göncüoglu (1997) and Göncüoglu & Kozlu (2000) advocated that both of these units were of Gondwanan origin and accreted to the Laurasian margin during the Variscan orogeny.

According to Kozur & Göncüoglu (2000) one of the most important differences between the Palaeozoic successions of these two terranes is the deposition of shallow-water carbonates and clastic rocks from the Late Devonian to the Serpukhovian in the Zonguldak Terrane which contrasts with the deposition of pelagic (nodular) limestones, radiolarian cherts and flysch-type sediments during the same period in the Istanbul Terrane. This feature is very critical in understanding the palaeogeographic positions of either terrane and necessitates further detailed investigation of the Upper Devonian-Lower Carboniferous rock units, especially in the Istanbul area. Previous studies subdivided the Devonian-Carboniferous rock-units in this area into numerous lithostratigraphic units, where different names were used for different formations (Kaya 1973; Tab. 1 for comparison of the stratigraphic nomenclature).

In this study the authors present their preliminary field data and conodont findings from the uppermost "Nodular Limestones" of the Istanbul area, in order to discuss the timing of the drowning of the Palaeozoic platform, and the onset of Variscan flysch deposition. The authors also correlate the Late Devonian-Early Carboniferous stratigraphy of the study area with the Zonguldak area in NW Turkey in order to evaluate its palaeogeographic position.

Stratigraphy

In the Istanbul and Gebze regions, Kaya (1973, 1988) differentiated the Istinye Formation of the Sedef Group (the lower part of the Devonian succession) and the Pendik Group including the rest of the Devonian succession (Fig. 2). From bottom to the top the Pendik Group includes the Kartal, Kozyatagi, Icerenköy and Büyükada formations. The Pendik Group is conformably overlain by the Baltalimani Formation, consisting of lydites and siliceous shales, which were dated by the prolific radiolarian fauna indicating an early to middle Tournaisian age (Holdsworth in Kaya 1973).

Detailed stratigraphic successions and fossil contents of the Devonian formations in Istanbul area are given in Kaya (1973) with contributions of C. Babin (bivalvia), P. Carls (strophomenids), J. Gandl (trilobites) and J. Kullman (goniatites and corals). The conodont fauna of these formations was studied by Abdüsselamoglu (1963), Haas (1968) and more recently by Capkinoglu (1997, 2000). These studies suggested that the deposition of the Devonian limestones terminated during the Late Devonian (Famennian).

The uppermost lithostratigraphic unit of the Devonian Pendik Group in the Istanbul-Gebze area is known as the Büyükada Formation (Kaya 1973). Önalan (1982) introduced "Tuzla Formation" as a new formation name for the Büyükada Formation. For reasons of priority we will follow the nomenclature of Kaya (1973).

The studied succession is located in the uppermost part of the Büyükada Formation and was named as the Ayineburnu Member (Kaya 1973). In the previous work, this unit was assigned to "Bänderschiefer und Nierenkalk" of Middle Devonian age within the "Nierenkalk-Kiesels-

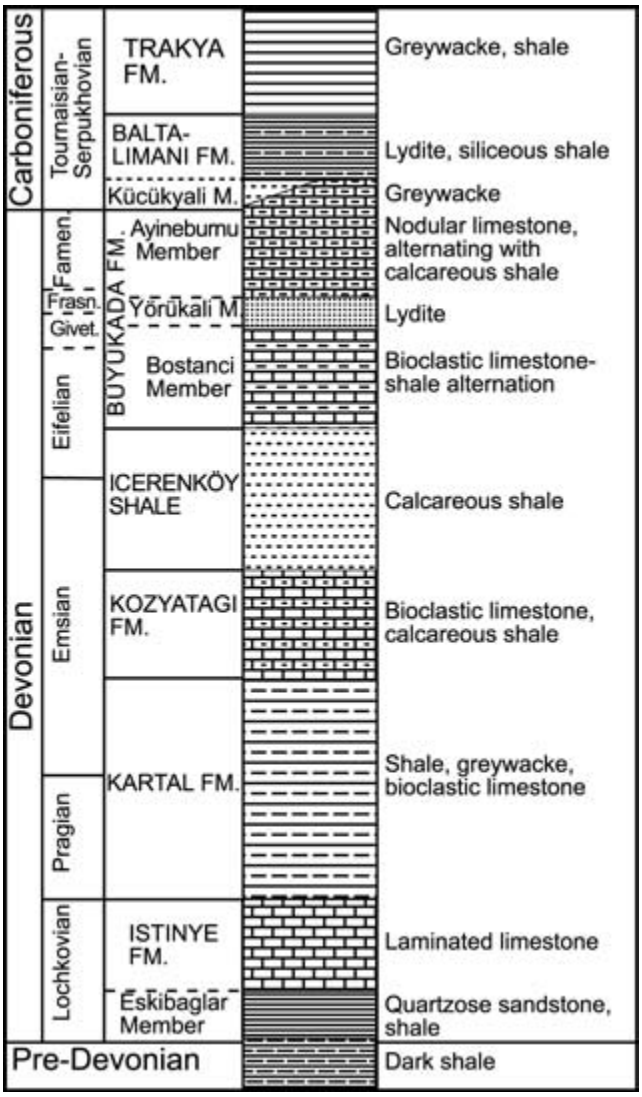

Fig. 2 - Generalized columnar section of the Late Silurian to Early Carboniferous units in Istanbul area (after Kaya 1973).

chiefer-Serie" by Paeckelmann (1938) or to the "calcaires noduleux" of Abdüsselamoglu (1963), that was dated by conodonts as late Frasnian-Famennian and Famennian. Haas (1968) assigned this unit to his "Denizli Schichten" of Late Devonian age. Capkinoglu (2000) described in detail the same unit in Gebze-Denizliköyü area, a few kilometres to the NE of the present study area.

At its type locality (Ayineburnu, Büyükada, Prince Islands in Marmara Sea) the thickness of this member is about 50 m, and includes yellowish grey to grey, micritic-biomicritic limestones and greyish white to grey, finely laminated and evenly bedded micritic limestones alternating with dark grey, calcareous shales. Nodules of brownish black to light grey cherts occur towards top of the succession.

The presently studied succession is located to the east of Istanbul, on the Istanbul-Ankara Highway (E-5) to the south of Gebze (Fig. 3). The outcrops described here are on the western slope of the road-cuttings at the BP tank-station on the highway at 44th km, where the transition between the nodular limestones of the Ayineburnu Member of the Büyükada Formation and the overlying shales and radiolarites of the Baltalimani Formation is clearly observed. The location corresponds to the boundary between Upper Devonian "nodular cherty limestone" unit (d-4 unit) and Lower Carboniferous "black radiolarian cherts with phosphate nodules" (k-1 unit) in the geological map of Abdüsselamoglu (1977).

The studied succession represents only the uppermost 5 m of the Ayineburnu Member (Fig. 4). The lower part of the succession is covered by talus deposits in the studied locality. The lower 1.5 m of the section is represented by yellowish-grey nodular limestones. The 3 to 5 cm nodules are elongated. The limestones are micritic and include only ostracode shells of about 10%. Two intervals of light-grey and laminated calcareous shales occur in this part. Above is a limestone level (0.3 m), differentiated by the presence of fine lamination and irregularly distributed chert nodules. The limestone is bluish-grey in colour and biomicritic. The following part is made up of a 1 m thick alternation of thin bands of calcareous shales and dark grey nodular limestone. The limestones here are micritic-biomicritic and include discontinuous bands and lenses of laminated cherts. The nodules in the limestone are flattened and up to 7 cm in length. A thick package (1.5 m) of yellowish-grey nodular limestone with very thin and yellow marly mudstone intercalations makes up the upper middle part of the succession. The nodules here are around 5 cm in length and display pinch and swell structures, compared with the underlying nodular limestone levels. The upper 1 m of the succession includes yellowish-grey nodular limestones with chert bands and layers. Under the microscope the limestone is micritic and includes radiolarians. The individual nodules are ellipsoidal and their length may reach 7 cm.

The conformably overlying 25 cm of dark brown to black siliceous shales above the last nodular limestone band and the upward following succession with lydites, black shale intercalations and phosphatic nodules are attributed to the Baltalimani Formation of Kaya (1973, 1980).

Along the studied section, 5 samples (of approximately 1 kg each) were collected, dissolved in acetic acid and handpicked for conodonts. Only one sample (Sample Tuz-1), 15 cm below the topmost nodular limestones with big and ellipsoidal nodules (diameter about 7 cm) yielded a few conodont elements.

Discussion and conclusions

The uppermost nodular limestone beds of the Ayineburnu Member of the Büyükada Formation include conodonts indicating the upper *sandbergi-crenulata* zones

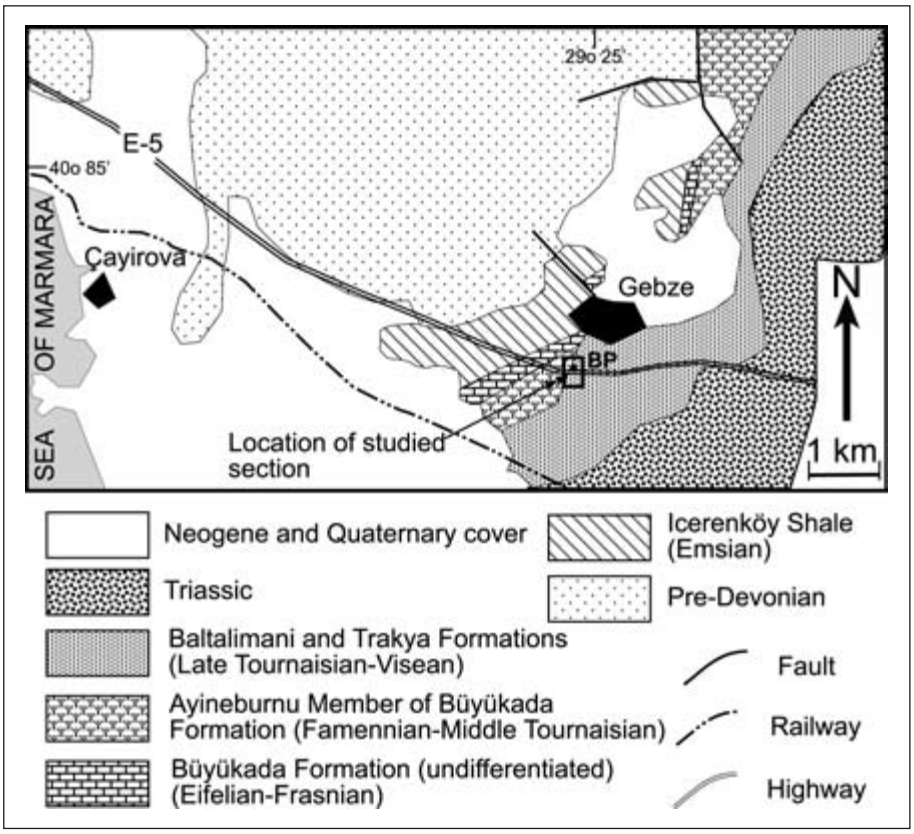

Fig. 3 - Simplified geological map of the Gebze area and the location of the studied succession (simplified after Haas 1968 and Abdüsselamoglu 1977).

of the middle Tournaisian. So far this is the first middle Tournaisian conodont record in an autochthonous succession in the Istanbul terrane in NW Turkey. The previously published conodont data (*Protognathus* cf. *praedelicatus*, *Polygnathus communis communis*, *Polygnathus purus* cf. *subplanus*, *Bispathodus stabilis*, and *Icriognathodus kayai* n. gen. n. sp.) of Gedik & Capkinoglu (1984) indicating the *isosticha*- Upper *crenulata* Zone was obtained from a micritic limestone pebble within the Mesozoic basal conglomerates and its original stratigraphic position is unknown.

In the previous studies, the upper age limit of the nodular limestones of the Ayineburnu Member was assumed to be late Famennian (Abdüsselamoglu 1963; Haas 1968; Önalan 1990; Görür et al. 1997). However, Kaya (1973) suggested that the deposition of Ayineburnu Member might reach up to the early Tournaisian, based on a probable early to middle Tournaisian radiolarian microfauna found within the overlying Baltalimani Formation. The conodont findings in this present study indicate that the deposition of the nodular limestones did not terminate prior to the middle Tournaisian. Moreover, the pelagic conodont fauna, together with the depositional features of the studied succession, suggest the deposition in a deep basin and not at a shallow ramp as previously suggested by Önalan (1990). The conformably overlying radiolarian cherts and black, organic-rich siliceous shales (Baltalimani Formation of Kaya 1980) further indicate that this basin was anoxic and deep enough for the deposition of bedded cherts with phosphate nodules. This interpretation also contrasts with the depositional model of Derman & Tuna (2000) for the Istanbul area, postulating that the deposition of the carbonates was in a shallow marine environment and until the end of Serpukhovian. The Baltalimani Formation is conformably overlain by the Trakya Flysch Formation, which yielded late Tournaisian fossils in its lowermost part (Kaya 1980). By this it is put forward that the transition from the classical "Schwellen"- to "Becken"-facies and the accommodation of flysch deposition occurred within a short period during the middle to late Tournaisian, as it is the case in the southern Variscan zone extending from North Africa to Central Europe through Spain during Late Devonian to Carboniferous (e.g. Reading 1982).

Another important implication of the present study is related to the location of the Devonian/Carboniferous boundary. Previous studies unequivocally suggested that the Ayineburnu Member represents a continuous succession (e.g. Kaya 1973). A recent conodont biostratigraphic study (Capkinoglu 2000) in the Denizliköyü area to the north of the present locality, has confirmed the presence of the Upper *expansa* Zone in the upper part of the Ayineburnu Member. Our new finding endorses the presence of the upper *sandbergi- crenulata* zones, together with the conodont data of Capkinoglu (2000), indicate that the Devonian/Carboniferous boundary should be located somewhere within the upper part of this member, which would make the Gebze area a promising location

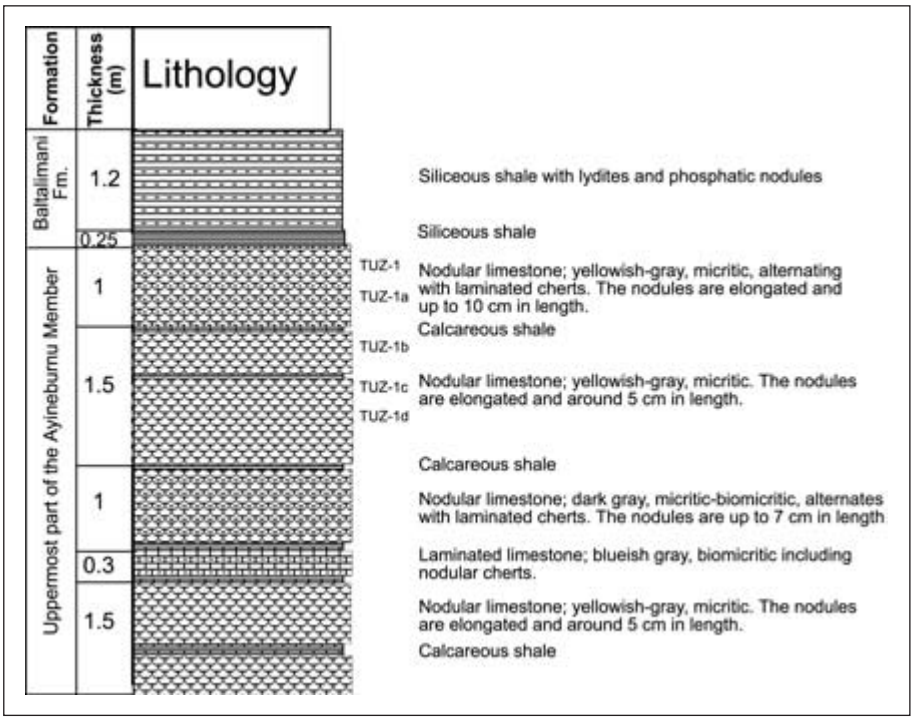

Fig. 4 - Stratigraphic log of the studied succession and the location of the conodont- bearing sample TUZ-1.

to study the conodont biostratigraphy at the Devonian/ Carboniferous boundary.

The last geological implication of this study is the correlation of the Early Carboniferous events within the Palaeozoic terranes in NW Anatolia. The conventional approach (e.g. Sengör 1984; Okay et al. 1994; Görür et al. 1997) is that the Istanbul and Zonguldak areas were parts of a single tectono-stratigraphic unit, situated along the southern border of the Moesian Platform and represents the external zones of the Variscan belt. Based on the fossil provinciality (Dean et al. 1997) and the succession of events (Göncüoglu 1997) the Istanbul and Zonguldak terranes are considered as Gondwana-derived microcontinents. They most probably were drifted together with some other terranes (for a review see Stampfli 1996; Kalvoda 2001, and von Raumer et al. 2002) from Gondwana and successively accreted to Baltica. For the NW Anatolian realm, Göncüoglu (1997) and Göncüoglu & Kozlu (2000) suggested that the Istanbul and Zonguldak terranes were already separated from the main continent during the Early Palaeozoic. However, the succession of events in these terranes indicates that they had a different accretional history. A similar scenario was proposed for the terranes in the Balkan region (Boncheva & Yanev 1993; Yanev & Boncheva 1997).

In the Zonguldak Terrane, the distinct latest Silurian-earliest Devonian unconformity and thermal event is ascribed to the collision of this with the Moesian terrane ("Caledonian time event" in Kozur & Göncüoglu, 2000) that was already accreted to the southern margin of Dobruca unit of Palaeo-Europe (Yanev & Boncheva 1997). The docking of Zonguldak and Moesian terranes was very probably realized along transformal boundaries, as no ophiolite-bearing accretionary complexes of Palaeozoic age were observed in NW Anatolia.

In the Zonguldak Terrane the Emsian to Sepukhovian deposition is mainly characterized by medium to thick-bedded limestones and dolomites that alternate with cherty limestones (e.g. Dil & Konyali 1978). In the Gökgöl Section, 3 km to the southeast of Zonguldak (Fig. 5), where a continuous Upper Devonian-Lower Carboniferous succession is observed, the upper Famennian (Fm2d) starts with thick-bedded limestones, followed by cherty limestones and sandy limestones. The Devonian-Carboniferous boundary here is located within an almost 3 m thick dolomite level that conformably overlies the sandy limestones. Upwards follows grey-cream to dark grey dolomites and sandy limestones that yielded fossils belonging to the *Quasiendothyra kobeitusana* Zone (Tn1a to lower Tn1b of western Europe, Dil & Konyali 1978). The middle Tournaisian in this section is represented by thick-bedded dolomites. The upper Tournaisian (Tn3) succession is mainly made up of cherty limestones and thick-bedded limestones. The Tournaisian-Visean transition in the Gökgöl section is represented by an alternation of thick-bedded cherty limestones and dolomites. The fossil data indicate that this succession does not include any depositional break and continues up to late Visean. Based on the faunal assemblages and petrographical features, Dil & Konyali (1978) suggest that the upper Famennian- late Visean reef and lagoonal limestones in the Zonguldak area are representative for shallow marine depositional environment. When correlated with the Upper Devonian- Lower

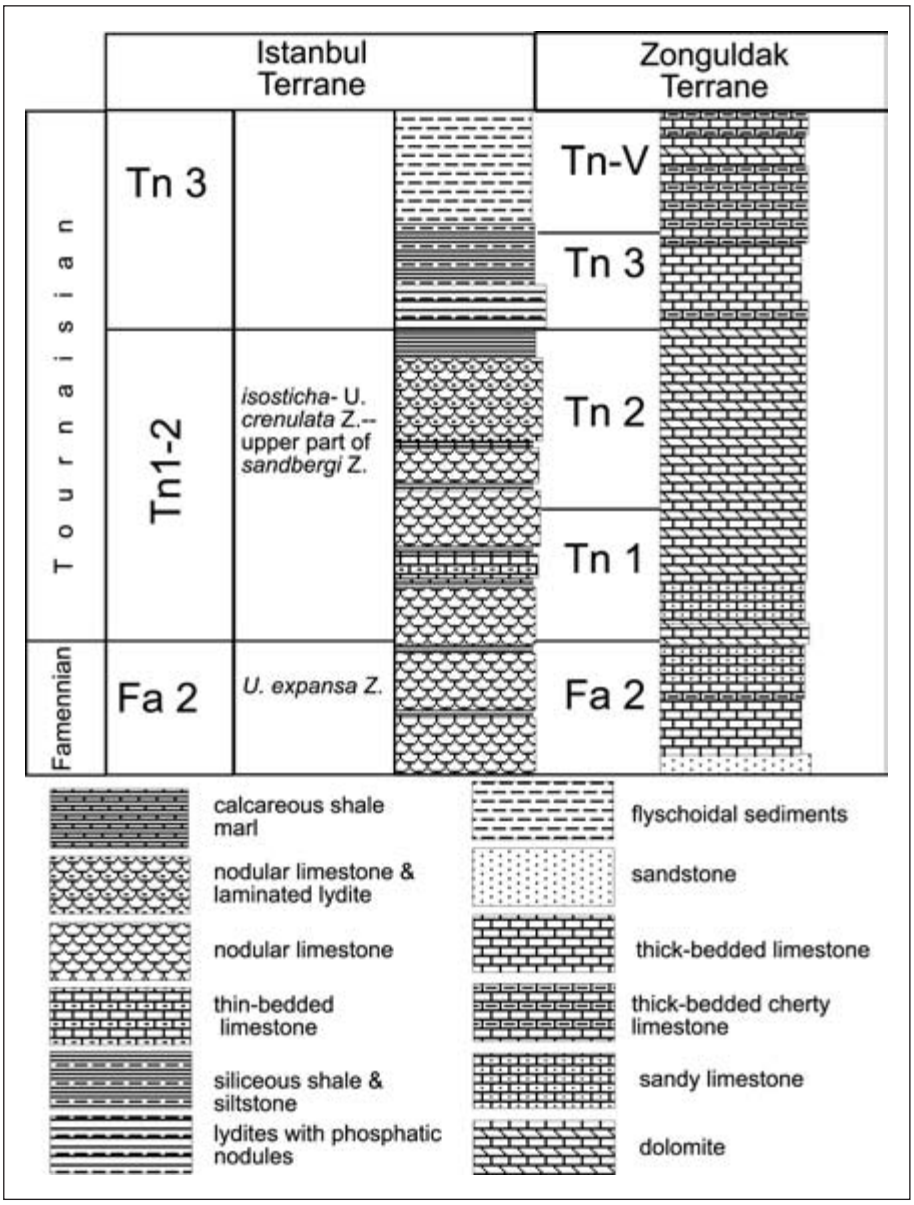

Fig. 5 - Correlation chart of Upper Devonian-Lower Carboniferous succession in Istanbul and Zonguldak terranes.

Carboniferous succession in the Istanbul area, it is obvious that these two successions were formed in quite different facies zones as suggested by various authors (Göncüoglu & Kozur 1998; Kozur & Göncüoglu 2000; Kalvoda 2001).

The development during the Visean to Westphalian interval in both areas is also important to understand the palaeogeographic settings of the Istanbul and Zonguldak terranes within the Variscan domain. The flysch-type sediments in the Visean-Namurian Trakya Formation in the Istanbul area include volcanic-volcaniclastic detritus (Kaya 1980). The detailed sedimentological studies (Kaya 1980; Önalan 1982; Derman & Tuna 2000) for the late Tournaisian to Namurian time interval in Istanbul region suggested that the volcanic detritus was mainly supplied from the north to northwest. This would imply that the Istanbul area was in a foredeep-type tectonic setting for the time concerned. During the same time-interval, in contrast to the Istanbul region, predominantly shallow platform conditions prevailed in the Zonguldak area. Lacustrine to fluvial clastic deposition with a detritus supply from north (Kerey 1985) and the formation of coal seams in the Zonguldak area during the Late Carboniferous suggests that there is neither a facial continuity nor a palaeobathymetric similarity between these two areas. This is further support for the suggestion of Göncüoglu & Kozur (1998) and Kozur & Göncüoglu (2000) that the Istanbul and Zonguldak areas should be considered as different terranes.

Systematic palaeontology and age assignmen1

The single sample (Tuz-1 from the uppermost part of the Ayineburnu Member of the Büyükada Formation) yielded only 4 conodont elements. All conodont elements are within a range of CAI 4, indicating burial temperatures (Epstein et al. 1977) about 190-300 °C and fall into the range of metagenesis.

Genus *Bispathodus* (Müller, 1962)

Type species: *Spathodus spinuilicostatus* E. R. Branson, 1934

Bispathodus stabilis (Branson & Mehl, 1934)

Plate 1, Figs 1, 2.

1934a *Spathodus stabilis* n. sp. Branson & Mehl, p. 188-189, pl. 17, fig. 20.
1969 *Spathognathodus stabilis* (Branson & Mehl) - Schöonlaub, p. 349, pl. 3, figs 14, 15.
1974 *Bispathodus stabilis* (Branson & Mehl) - Ziegler et al., p. 103-104, pl. 3, figs 1-3.
1999 *Bispathodus stabilis* (Branson & Mehl) - Mawson & Talent, p. 412, pl. 1, figs 1-6.

Remarks. The Turkish specimens are well preserved and are very close to the type material described in the original diagnosis. *B. stabilis* is the only species of the *Bispathodus* group that does not have accessory denticles on the right side of the blade - the so called single-rowed species of *Bispathodus*. The basal cavity is large, with extensions of each side of the blade in *B. stabilis* Morphotype 1 (Pl.1, fig. 2). *B. stabilis* Morphotype 2 (Pl., fig. 1) is with prothognathodid-like basal cavity and reaches the posterior tip of the blade.

Stratigraphic occurrence. According to Ziegler & Sandberg (1984, fig. 4) the *Bi. stabilis* Morphotype 1 ranges from the base of the Upper *marginifera* Zone - (Age: Famennian -Late Devonian) to the *isosticha*- Upper *crenulata* Zone- (Age: middle Tournaisian - Early Carboniferous); *Bi. stabilis* Morphotype 2 ranges from the base of the Lower *expansa* Zone (former Upper styriacus Zone)- (Age: Famennian- Late Devonian) through the *isosticha*- Upper *crenulata* Zone - (Age: middle Tournaisian - Early Carboniferous). In Capkinoglu (2000, p. 93) the Lower *expansa* Zone has been recognized on the base of the occurrence of *Bi. stabilis* Morphotype 2.

Genus *Siphonodella* Branson & Mehl, 1934

Type species: *Siphonognathus duplicata* Branson & Mehl, 1934

Siphonodella lobata (Branson & Mehl, 1934)

Plate 1, Fig. 3.

1934 *Siphonognathus lobata* n.sp. Branson & Mehl, p. 297, pl. 24, figs 14-15.
1966 *Siphonodella lobata* (Branson & Mehl)- Klapper, p. 16, pl. 2, figs 1-4
1969 *Siphonodella lobata* (Branson & Mehl) - Rexroad, p. 43-44, pl. 2, figs 5-8.
1969 *Siphonodella lobata* (Branson & Mehl) - Schönlaub, p. 345, pl. 2, figs11-12.
1993 *Siphonodella lobata* (Branson & Mehl) – Ji & Ziegler, pl.41, figs 15-16.

Remarks. The figured specimen is very close to the type material of Klapper (1966) with well-developed outer lobe bearing a secondary carina (with 2-3 nodes). Strongly arched asymmetrical platform with a parapet ornamented by equal transverse ridges.

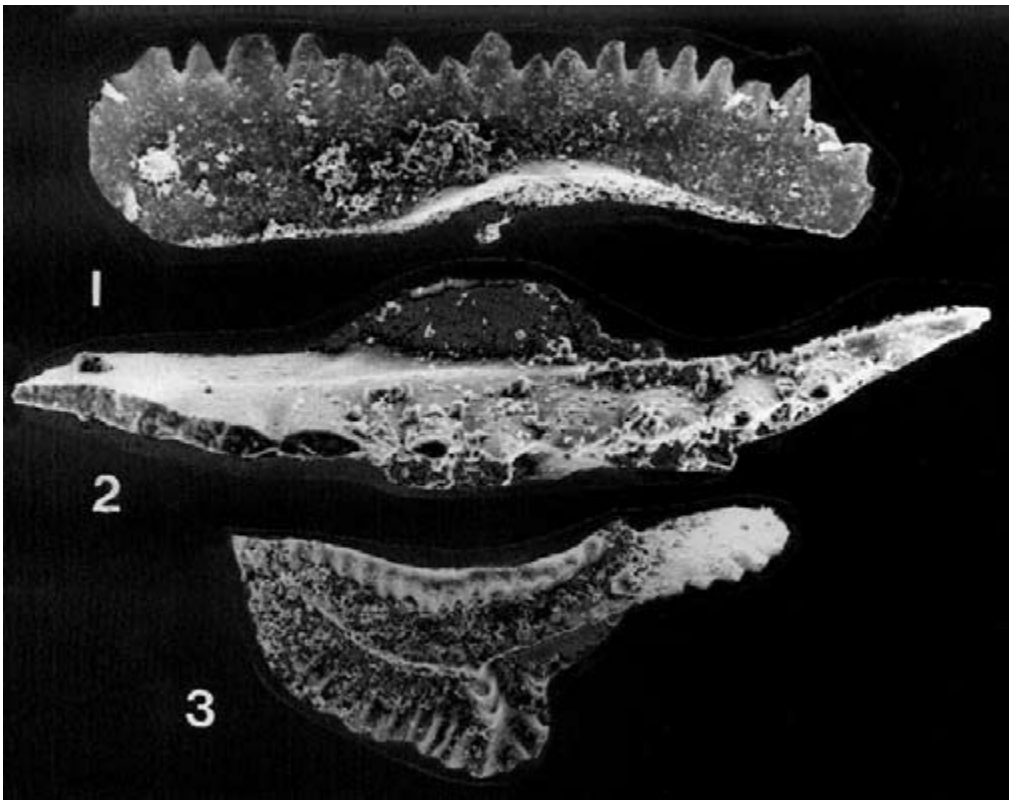

PLATE 1

Sample Tuz-1 from the uppermost part of the Ayineburnu Member of the Büyükada Formation in Gebze area, eastern Istanbul, NW Turkey. The figured material is reposited at the palaeontology collection of the Department of Geological Research, General Directorate of Mineral Research and Exploration, Ankara. Fig. 1 - *Bispathodus stabilis* (Branson & Mehl, 1934), morphotype 2, lateral view, rep.-no: TUZ-1/17, x100. Fig. 2 - *Bispathodus stabilis* (Branson & Mehl, 1934), morphotype 1, upper view, rep.-no: TUZ-1/16, x230. Fig. 3 - *Siphonodella lobata* (Branson & Mehl, 1934), upper view, rep.-no: TUZ-1/14, x60.

Stratigraphic occurrence. *Siphonodella duplicata* Morphotype 3 gives rise by the expansion of the anterior portion of the outer platform to *Siphonodella lobata* within the *sandbergi* Zone (Ji & Ziegler 1993). The range of *Siphonodella lobata* is from the upper part of the *sandbergi* Zone through the *isosticha* -Upper *crenulata* Zone (Sandberg et al. 1978; Ji & Ziegler 1993) (Age: middle Tournaisian - Early Carboniferous).

The single sample Tuz-1 from the uppermost part of the Ayineburnu Member of the Büyükada Formation which yielded the conodont elements: *Bispathodus stabilis* and *Siphonodella lobata* can be referred to the interval from the upper part of the *sandbergi* Zone through the *izosticha*- Upper *crenulata* Zone - middle Tournaisian - Early Carboniferous.

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