Lithofacies and Biofacies Characteristics of Lower Carboniferous Carbonates in Central Taurides, Turkey

Ayse Atakul-Ozdemir 1, Demir Altiner 2, Sevinc Ozkan-Altiner 2

1 Van Yuzuncu Yil University, Van, Turkey
2 Middle East Technical University, Ankara, Turkey

aozdemir@yyu.edu.tr

Abstract. The studied successions in the Central Taurides were mainly deposited in a shallow marine environment during the Early Carboniferous time. Conodonts are one of the most important microfossil groups for the Lower Carboniferous biostratigraphy. The measured sections are not rich in conodonts but important species including those of the Lower Carboniferous boundary conodonts. The conodont elements recorded in this study include Gnathodus cuneiformis, Gnathodus girtyi girtyi, Gnathodus girtyi simplex, Kladognathus sp., Lochriea commutata and Vogelgnathus campbelli. Based on the recovered conodont assemblages, Visean - Serpukhovian boundary has been recognized by the first occurrence of Gnathodus girtyi simplex. Conodont faunal variations in Paleozoic to Triassic marine deposits are generally environmentally controlled. Within the context of paleoenvironmental interpretations, different microfacies types could be determined by microfacies criteria reflecting patterns of the depositional environments. The types of microfacies and their environmental interpretations can provide a framework for conodont paleoecology. The defined facies types in BSE section are mainly crinoidal bioclastic packstone, bioclastic grainstone, sandy oolitic grainstone, quartz-peloidal grainstone and quartz arenitic sandstone facies. Crinoidal bioclastic packstones and bioclastic grainstones are suitable facies for conodonts owing to environmental conditions. Bioclasts associated with the conodonts are mainly crinoids, fusulinids, algae, echinoids, brachiopods and ostracods. Conodont elements could not be recorded from sandy oolitic grainstone and quartz arenitic sandstone facies due to the deposition in high energy environments under unstable conditions.

1. Introduction
Conodonts are one of the most important fossil groups for biostratigraphic studies in Paleozoic and Triassic marine deposits. They are resistant microfossils owing to their small size and calcium phosphate composition. They are the main tool used in this study for delinating the boundaries. A detailed taxonomical analysis and microfacies studies have been carried out through the samples collected from the Lower Carboniferous carbonates in Central Taurides, Turkey. Conodont faunal variations in Paleozoic to Triassic marine deposits are generally environmentally controlled. Some conodonts were limited to shallow water environments, others to deep waters, and some forms occur in both environments. Within the context of paleoenvironmental interpretations, different microfacies types could be determined by microfacies criteria reflecting patterns of the depositional environments. The types of microfacies and their environmental interpretations can provide a framework for conodont paleoecology. Other objectives of this study are to display types of microfacies, the depositional environments and discuss the relationship between the species of conodont taxa and microfacies types.
2. Geological setting and measured sections

The Tauride Belt comprises several tectono-stratigraphic units. Most detailed classification of these units was suggested by [1–5]. These are Geyik Dağı (autochthonous-parautochthonous unit), Aladağ, Bolkar Dağı, Bozkır, Antalya and Alanya Units (allochthonous units) [1,2]. Within these tectonostratigraphic units, the Aladağ Units is the main concern of this study since it contains in its stratigraphy well-developed Paleozoic carbonate sequences.

The Aladağ Unit is characterized by shelf type carbonate and clastic deposits of Late Devonian - Late Cretaceous [2,3,6]. [7] described the Paleozoic, mainly Carboniferous, units of Bademli region. The Carboniferous Yarıcak Formation of the Aladağ Unit is characterized by mainly quartzarenitic sandstone and limestone intercalations and dark colored shales.

In order to delineate and interpret the environmental changes across the Lower Carboniferous boundaries stratigraphic sections have been measured and sampled in Carboniferous deposits of the Aladağ Unit exposed around Bademli (Akseki) in the Central Taurides (Figure 1, 2, 3, 4).

![Geological map of the Bademli region](image)

**Figure 1.** Geological map of the Bademli region (modified from [8]). BT, BS and BSE are the measured sections.
Figure 2. Locations of the BS-section (A) and BSE-section (B) (Bademli, Central Taurides), red dots indicate the conodont sampling points.
Figure 3. Columnar section of the BS section in the Bademli region Central Taurides, the red arrows indicate the conodont sampling points.
Figure 4. Columnar section of the BSE section in the Bademli region, the red arrows indicate the conodont sampling points.
3. Materials and Methods
A total of 15 samples were collected for microfacies and microplaeontological studies from these sections. Detailed microfacies and microplaeontological studies were carried out and thin sections were prepared from each sample for petrographic analysis. Different microfacies types have been determined by the analysis of bioclastic components, and sedimentological features observed in thin sections based on [9].

4. Biostratigraphy
Conodonts are one of the main microfossil groups used to date and correlate the Paleozoic rocks. The conodont fauna recovered in the Taurides are less diversified and low in abundance. Several beds within the measured sections in Taurides are barren of conodonts, while others contain not very abundant, but quite important taxa. Based on the first appearance of biostratigraphically significant species, the following zones were established across the studied sections.

**Gnathodus girtyi girtyi Zone** The lower boundary of this zone is defined by the first appearance of the *Gnathodus girtyi girtyi* (Figure 5). The top of this zone is marked by the first appearance of *Gnathodus girtyi simplex*. This zone in the Taurides yields long ranging conodont taxa including *Gnathodus girtyi girtyi*, *Lochriea commutata* and *Kladognathus* sp. [10] reported the first occurrence of *Gnathodus girtyi girtyi* at the base of *Gnathodus bilineatus* Zone in the Asbian substage but [11] recorded this subspecies earlier, especially from Arundian stage. [12] reported this taxon mainly in upper Visean rocks in the Lublin Basin (Poland). In this study the elements of *Gnathodus girtyi girtyi* have been described from Upper Visean to Lower Serpukhovian rocks.

**Gnathodus girtyi simplex Zone** The lower limit of this zone is marked by the first appearance of the index species. The accompanied conodont fauna contains *Lochriea commutata*, *Gnathodus girtyi girtyi*, *Gnathodus cuneiformis*, *Vogelgnathus campbelli* and *Kladognathus* sp. (Figure 5). *Gnathodus girtyi simplex* is an important conodont taxon that became extinct at the Mid-Carboniferous boundary. This species originated at the base of Serpukhovian and evolved from the *Gnathodus girtyi girtyi*. *Gnathodus girtyi simplex* has been described in the lowest Serpukhovian beds in the Cantabrian Mountains, Spain [13] and in the Southern Urals [14].

5. Visean - Serpukhovian Boundary
The first appearance of *Lochriea ziegleri* in the lineage *Lochriea nodosa - Lochriea ziegleri* is currently under investigation as a marker for the GSSP identifying the Visean - Serpukhovian boundary. [14] described the *Lochriea ziegleri* Zone in the Verkhnyaya Kardailovka Section (South Urals) by the first appearance of *Lochriea ziegleri*. The conodont assemblages of *Gnathodus girtyi simplex*, *Gnathodus pseudosemiglaber* *Gnathodus bilineatus bilineatus*, *Gnathodus girtyi girtyi*, *Lochriea costata*, *Lochriea monocostata* and *Lochriea mononodosa* have also been reported from this zone. [15] documented conodont zonation for Silesian Subsystem in Great Britain and Ireland. In this study the *Kladognathus - Gnathodus girtyi simplex* Zone is defined in the Pendleian Stage and is characterized by the occurrences of *Gnathodus bilineatus bilineatus*, *Gnathodus girtyi girtyi*, *Gnathodus girtyi intermedius*, *Lochriea commutata*, *Lochriea nodosa*, *Lochriea mononodosa*, *Neoprinoidus spathatus* and *Kladognathus macrodentata*. The base of this zone corresponding to the Visean - Serpukhovian boundary is marked by the first occurrence of *Gnathodus girtyi simplex* [13,15]. The BS and BSE sections cropping out in the Bademli region have been measured in order to determine the Visean - Serpukhovian boundary by conodont biostratigraphy. Based on the recorded conodont assemblages, this boundary has been recognized within the BSE section by the first appearance of *Gnathodus girtyi simplex* in the Taurides, Turkey (Figure 5).
Figure 5. The Visean - Serpukhovian boundary conodont zonation in the BSE section in the Bademli region in the Central Taurides (S:System, St: Stage, SN: Sample Number, CZ: Conodont Zones).

6. Microfacies types and Depositional Environments
The studied BSE section in the Bademli region including the Visean - Serpukhovian boundary is predominantly composed of uniform lithologies of limestone, sandstone and sandy limestones. The defined microfacies types in the BSE section are crinoidal bioclastic packstone, bioclastic grainstone, sandy oolitic grainstone, quartz-peloidal grainstone and quartz arenitic sandstone facies (Figure 6, 7). Based on the microfacies types and recorded fauna, it can be concluded that these formations were deposited in a shallow water shelf environment.
Figure 6. Photomicrographs of microfacies determined in the BSE section in the Bademli region (Central Taurides). A-B bioclastic grainstone (sample BSEc 4), C-D crinoidal bioclastic packstone (sample BSEc 7) (cr: crinoid fragments; f: foraminifera; p: peloids; q: quartz grains). Horizontal bar is 500 μm.

Figure 7. Photomicrographs of microfacies determined in the BSE section in the Bademli region (Central Taurides). A-B sandy oolitic grainstone (sample BSEc 5), C quartz-peloidal grainstone (sample BSEc 3), D quartz arenitic sandstone (sample BSEc 1) (so: superficial ooid; f: foraminifera; q: quartz grains). Horizontal bar is 500 μm.
In the Central Taurides, the Visean - Serpukhovian boundary section (BSE) is mainly composed of shallow marine carbonate and sandstone deposits. The conodont assemblages from the BSE section in the Central Taurides (Turkey), exhibit a mixed ecological composition where typical offshore fauna like *Gnathodus girtyi girtyi*, *Gnathodus girtyi simplex* and *Lochriaea* [12] recorded together with the genera that dwelled relatively near shore environments with high energy and variable salinity, such as *Polygnathus mehli mehli*, *Vogelgnathus campbelli* and *Kladognathus*. Thus the depositional setting of the Bademli Limestone (BSE section) in the Bademli region is interpreted as shallower shelf environments. In this study the conodonts have been mainly obtained from crinoidal bioclastic packstone facies and a few elements have been recorded from quartz-peloidal grainstone. Crinoidal bioclastic packstones and bioclastic grainstones are very appropriate facies for conodonts owing to environmental conditions. Bioclasts associated with the conodonts are mainly crinoids, fusulinids, algae, echinoids, brachiopods and ostracods. No conodont elements have been recorded from sandy oolitic grainstone and quartz arenitic sandstone facies since these facies were mainly deposited in high energy environments under unstable conditions.

7. Conclusions
Conodonts are, undoubtedly, important biostratigraphic tools for the Paleozoic and Triassic deposits and primarily used in this study to delineate the Lower Carboniferous stage boundaries. Conodont elements recovered in the studied section in Central Taurides occur in low abundance, however, the section contains important Lower Carboniferous conodonts. Based on the appearance of biostratigraphically significant species, the following zones were established across the studied section: *Gnathodus girtyi girtyi* Zone (Late Visean) and *Gnathodus girtyi simplex* Zone (Early Serpukhovian). The Visean - Serpukhovian boundary in the Taurides from BSE section (Bademli) has been recognized by the first appearance of *Gnathodus girtyi simplex*. The studied successions in the Central Taurides were mainly deposited in a shallow marine environment during the Carboniferous time so they comprise less diversified conodont fauna and the conodont elements are low in abundance. The defined facies types in BSE section are crinoidal bioclastic packstone, bioclastic grainstone, sandy oolitic grainstone, quartz-peloidal grainstone and quartz arenitic sandstone facies. Based on the microfacies studies it can be stated that conodont elements essentially obtained from the crinoidal bioclastic packstones and bioclastic grainstone facies in the studied sections. These facies mainly include high amount of crinoid fragments and other bioclasts, such as foraminifers, ostracodes, echinoids and brachiopods. Consequently, it can be concluded that the occurrence of abundant crinoids are indicative criteria for the presence of conodonts.

References
[1] N. Özgül, "Stratigraphy and tectonic evolution of the Central Taurides." *Geol. Taurus Belt. Int. Symp. 1983, Ankara* 77–90, 1984.
[2] N. Özgül, "Some geological aspects of the Taurus orogenic belt-Turkey" *Soc. Turkey Bull. 19* 65–78, 1976.
[3] D. Altuner and N. Özgül, "Carboniferous and Permian of the allochthonous terranes of the Central Tauride Belt", *International Conference on Paleozoic Benthic Foraminifera, Paleoforams* (Ankara, Turkey: International Conference on Paleozoic Benthic Foraminifera, Guide Book, Paleoforams) pp 1–35, 2001.
[4] A.M.C. Şengör and Y. Yilmaz, "Tethyan evolution of Turkey - a plate tectonic approach" *Tectonophysics 75* 181–241, 1981.
[5] M. C. Goncuoglu, S. Capkinoğlu, S. Gursu, P. Noble, N. Turhan, U. K. Tekin, C. Okuyucu and Y. Goncuoglu, "The Mississippian in the Central and Eastern Taurides (Turkey): constraints on the tectonic setting of the Tauride-Anatolide Platform" *GEOL CARPATH*, 2007.
[6] N. Ozgul and A. Tursucu, "Stratigraphy of the Mesozoic carbonate sequence of the Munzar Mountains (eastern Taurides)." *Geol. Taurus Belt. Int. Symp. 1983, Ankara* 173–80, 1984.
[7] M. Gutnic, O. Monod, A. Poisson and F. Dumont, "Géologie des Taurides Occidentales..."
(Turquie)" Mémoires dela Société Geol. Fr. 137 1–112, 1979.

[8] O. Monod, Recherches géologiques dans le Taurus occidental au Sud de Beysehir (Turquie) (Université de Paris-Sud, Centre d’Orsay), 1977.

[9] E. Flügel, Microfacies of Carbonate Rocks. Analysis, Interpretation and Application. (New York: Springer-Verlag), 2004.

[10] I. Metcalfe, "Conodont zonation and correlation of the Dinantian and early Namurian strata of the Craven lowlands of northern England" Rep. Inst. Geol. Sci. 80 1–70, 1981.

[11] W. J. Varker and G. D. Sevastopulo, "The Carboniferous System: Part 1 Conodonts of the Dinantian Subsystem from Great Britain and Ireland" Stratigraphic Index of Conodonts ed A C Higgins and R L Austin (Chichester) pp 167–209, 1985.

[12] S. Skompski, A. Alekseev, D. Meischner, T. Nemirovskaya, M. F. Perret and W. J. Varker, "Conodont distribution across the Viséan/Namurian boundary" Cour. Forschungsinstitut Senckenb. 188 177–209, 1995.

[13] T. I. Nemyrovska, "Late Viséan/early Serpukhovian conodont succession from the Triollo section, Palencia (Cantabrian Mountains, Spain)" Scr. Geol. 129 13–89, 2005.

[14] V. N. Pazukhin, E. I. Kulagina, S. V. Nikolaeva, N. N. Kochetova and V. A. Konovalova, "The Serpukhovian Stage in the Verkhnyaya Kardailovka section, South Urals" Stratigr. Geol. Correl. 18 269–289, 2010.

[15] A.C. H., "The Carboniferous system: Part 2-Conodonts of the Silesian subsystem from Great Britain and Ireland" A stratigraphycal index of conodonts ed I A.C. and A R.L. (Chichester) pp 210–7, 1985.