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## BASHKIRIAN/MOSCOVIAN BOUNDARY BASED ON FUSULINID FORAMINIFERA IN HADIM NAPPE SECTIONS FROM THE TAURIDE BELT, TURKEY: A REVIEW OF BIOSTRATIGRAPHIC DATA

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### Abstract

The Hadim Nappe which is one of the allochthonous unit in the Tauride Belt consists of carbonate dominated succession from the Middle(?)–Late Devonian to Late Cretaceous. The Paleozoic carbonate rocks of this Nappe are well-exposed and allow a detail biostratigraphic control for the boundary of the stage transitions. The description of the Bashkirian/Moscovian boundary which is one of the main topics of the Carboniferous stratigraphy is still controversial and has not a GSSP (Global Boundary Stratotype Section and Point). The main studies for the description of Bashkirian/Moscovian boundary are focused on some conodont lineages but also fusulinid foraminifera are good tools for this boundary. Based on the classical approaches for the Bashkirian/Moscovian boundary, the upper Bashkirian is represented by *Tikhonovichiella tikhonovichi* and *Verella spicata* and the base of Moscovian is characterized by *Aljutovella aljutovica* fusulinids in the Tethyan Realm. The Bashkirian/Moscovian boundary in Hadim Nappe is characterized by a very shallow marine carbonates and this boundary is determined by fusulinid foraminifera due to the absence of conodonts. According to the previous studies except some superficial ones carried out in eastern and central Taurides, the upper Bashkirian and lower Moscovian strata include typical marker fusulinid assemblages for the description of this boundary.

**Keywords:** Tauride Belt, Hadim Nappe, Bashkirian, Moscovian, Fusulinid

### 1. Introduction

The Taurides, one of the major units of the Alpine-Himalayan Orogenic Belt, is geographically subdivided into three regions by Özgül (1976, 1984) as (1) Eastern Taurides, (2) Central Taurides and (3) Western Taurides (Fig. 1). It consists of autochthonous (Anamas-Akseki-Beydağları autochthonous) and allochthonous (Hadim, Beyşehir-Hoyran, Bolkar Dağ, Alanya and Antalya Nappes) units (Blumenthal 1944, 1951; Gutnic et al. 1968, 1979; Brunn et al. 1970, 1971; Özgül 1976, 1984, 1997; Monod 1977; Turan 1990). The Hadim Nappe which is one of the allochthonous unit in the Tauride Belt has extensive outcrops in the eastern, central and western Taurides and these are mainly composed of platform type shallow-marine carbonates and siliciclastic rocks ranging from Middle(?)–Upper Devonian to Upper Cretaceous (Fig. 2) (Özgül 1971, 1997; Güvenç 1965, 1977a; Monod 1977; Turan 1990). The Mississippian subsystem of the Carboniferous is mainly composed of shale and siltstone intercalations at the base (Tournaisian), carbonates with shale interbeds at the middle (Visean) and mainly quartz arenite sandstones and rare carbonates (limestone, oolitic limestone) at the top (Serpukhovian). The Lower to Middle Pennsylvanian (Bashkirian-Moscovian) interval of the Carboniferous comprise dominantly carbonates. The Kasimovian succession commonly has a basal sandstone overlain by carbonates and the Gzhelian is characterized by an alternation of sandstone and limestone with *Girvanella* limestone (Calcaires à Girvanelles) facies (Güvenç 1965) along to the Upper Pennsylvanian to Cisuralian. The Pennsylvanian carbonate dominated and rich in fusulinids succession of the Hadim Nappe allow to determined stage boundaries with a detailed biostratigraphy.

The upper Bashkirian across the Bashkirian/Moscovian boundary is characterized by occurrence of *Tikhonovichiella tikhonovichi* (Rauzer-Chernousova, 1951) and *Verella spicata* Dalmatskaya, 1951 fusulinids (Richards 2013; Alekseev 2017). The base of the Moscovian stage where is indicated the



Bashkirian/Moscovian boundary, was originally described based on brachiopods, then it was defined by fusulinid species *Aljutovella aljutovica* (Rauzer-Chernousova, 1938) which occurs 3 meters above the occurrence of the conodont *Declinogathodus donetzianus* Nemirovskaya, 1990 within the Aljutovskaya Formation in its stratotype (Makhlina et al. 2001). There are some marker fusulinid and conodont taxa to define the Bashkirian/Moscovian boundary but there is no formal GSSP yet. The conodonts *Diplognathodus ellesmerensis* Bender, 1980 and *Declinognathodus donetzianus* Nemirovskaya, 1990 have been proposed as potential index fossils for the base of Moscovian stage by SCCS task-group (Richards 2013; Alekseev 2017).

The first biostratigraphical subdivision of Carboniferous-Permian units of the Hadim Nappe sections was carried by Güvenç (1965 1977a, 1977b) mainly based on calcareous algae. For this reason, the foraminiferal composition of the Güvenç's studies (1965, 1977a, 1977b) is not evaluated in this study. The foraminifera-based biostratigraphy of the Bashkirian/Moscovian boundary studies in Hadim Nappe were realized by Altınır (1981) and Dzenchuraeva and Okuyucu (2007) in eastern Taurides, and by Altınır and Özgül (2001), Akbaş (2020) in central Taurides (Fig. 2). Although this boundary can be determined based on fusulinids in Hadim Nappe sections, there are some biostratigraphic discrepancies which mainly related to the differences of the depositional environments of the successions including Bashkirian/Moscovian boundary strata. For this purpose, the main goal of this study is the review and correlation of boundary studies.

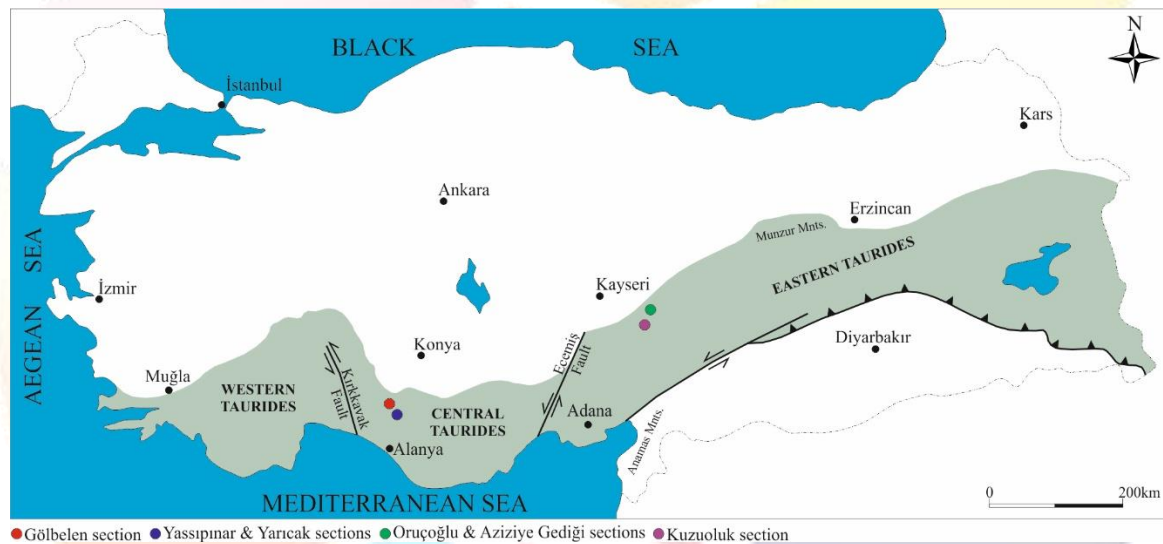


Figure 1. The geographical subdivision of Tauride Belt and location of the sections (simplified after Özgül, 1984).



SYSTEM/SERIES	FORMATION	THICKNESS (m)	LITHOLOGY	EXPLANATION
U. C.	PERMIAN	5900		Debris flow deposits (olistostromes)
		5700		Conglomerate, sandstone Unconformity
JURASSIC-CRETACEOUS	CAMLIK	4600		Limestone, dolomite
				Argillaceous limestone, sandstone, Conglomerate, lacustrine limestone
TRIASSIC	DURULUCAK			Unconformity
				Sandstone, sandy limestone, limestone, shale
PERMIAN	CEVIZLI	3500		Stromatolitic and oolitic limestone
				Limestone, shale, sandstone
MIDDLE (?)-UPPER DEVONIAN	ASARLIKAYTA	2410		<i>Girvanella</i> limestone
		1500		Limestone, oolitic limestone, sandstone, dolomite
MIDDLE (?)-UPPER DEVONIAN	ASARLIKAYTA			Shale, siltstone intercalations
				Sandstone, shale, sandy limestone, reefal limestone, dolomite
				Dolomite

Figure 2. Generalized columnar section of the Hadim Nappe (modified after Monod 1977; Turan 1990; Okuyucu & Güvenç 1997; Özgül 1997). Key: U. C., Upper Cretaceous.

## 2. Biostratigraphy

The upper Bashkirian-lower Moscovian carbonate dominated strata of the Hadim Nappe contains a diverse and rich marine fossil biota including echinoids, bryozoans, bivalves, crinoids, calcareous algae and fusulinids. The fusulinid fauna of this interval allow a biostratigraphic control for boundary stages. Altiner (1981) has studied the Bashkirian-Moscovian successions on two measured sections namely Oruçoğlu and Aziziye Gediği sections based on foraminifera (Fig. 3). The upper Bashkirian was represented by *Pseudostaffella antiqua* (Dutkevitch, 1934), *P. compressa* (Rauzer-Chernousova, 1938), *P. korobezkikhi* Rauzer-Chernousova and Safanova in Rauzer-Chernousova et al., 1951, *Eostaffella* sp., *Ozawinella* sp. and *Profusulinella parva* (Lee and Chen in Lee et al., 1930) in the Oruçoğlu and Aziziye Gediği sections, and *Profusulinella parva* was marked as zonal fossil of this interval (Altiner, 1981). On the other hand, the Vereian substage of the lower Moscovian was characterized by *Eostaffella mutabilis* Rauzer-Chernousova, 1951 and *Aljutovella* cf. *aljutovica* (Rauzer-Chernousova, 1938) zone fossils in the Aziziye Gediği section whereas the Vereian and Kashirian substages of this interval could not be separated based on fusulinid foraminifera (Fig. 3). *Aljutovella aljutovica*, the marker of the base of the Vereian substage, was absent in the Oruçoğlu section. Another research on Bashkirian/Moscovian boundary in eastern Taurides was carried out by Dzhenchuraeva and Okuyucu (2007) at the Kuzuoluk section. In Kuzuoluk section the uppermost Bashkirian of the Hadim Nappe was characterized by the occurrence of the *Verella spicata* which was indicated as zonal marker fossil of this interval by Dzhenchuraeva and Okuyucu (2007) (Fig. 3). Additional to this, the *Pseudostaffella* ex gr. *antiqua*, *Profusulinella parva* and *Aljutovella tikhonovichi* Rauzer-Chernousova, 1951 (= *Tikhonovichiella tikhonovichi* in this study) which is the other useful index fusulinid foraminifera of the upper Bashkirian were found at the Kuzuoluk section in eastern Taurides (Dzhenchuraeva and Okuyucu, 2007). The base of the Moscovian across the Bashkirian/Moscovian boundary was indicated by the



first occurrence of the *Aljutovella aljutovica* which is associated with other important lower Moscovian fusulinid foraminifera such as *Schubertella obscura* Lee and Chen in Lee et al., 1930, *Ovatella subovata* (Safonova in Rauzer-Chernousova et al., 1951) (= *Solovievaia subovata* in this study), *Profusulinella pararhomboides* Rauzer-Chernousova and Belyaev in Rauzer-Chernousova et al., 1936 at the Kuzuoluk section in eastern Taurides (Dzhenchuraeva and Okuyucu, 2007) (Fig. 3).

The Bashkirian-Moscovian succession of the Hadim Nappe in central Taurides had studied at three sections, two of them in Hadim town studied by Altınır and Özgül (2001) and Akbaş (2020) and one of them in Bozkır town by Akbaş (2020) (Fig. 3). The uppermost Bashkirian of the Hadim Nappe correspond to the *Profusulinella* zone which is defined by the first appearance of primitive species of this genus (Altınır and Özgül, 2001) (Fig. 3). According to the authors this zone comprises *Pseudostaffella antiqua*, *P. antiqua grandis* Schlykova in Grozdilova and Lebedeva, 1950, *P. praegorskyi* Rauzer-Chernousova, 1949, *Profusulinella bona* Grozdilova and Lebedeva, 1954, *P. parva*, *P. rhomboides?* (Lee and Chen in Lee et al., 1930), *P. rhombiformis?* Brazhnikova and Potievskaya, 1948, *P. primitiva?* Sosnina in Grozdilova and Lebedeva, 1954, *P. staffellaeformis* Kireeva in Rauzer-Chernousova et al., 1951 (= *Staffellaeformis staffellaeformis* in this study), *Eostaffella* spp. and *Ozawainella* spp., and they also indicated that the obtained species of *Profusulinella* from this zone characteristic for the last two horizons (Tashastinsky and Asataussky) of the Bashkirian stage. The lower Moscovian including Vereian and Kashirian substages was determined by the occurrence of the *Eostaffella mutabilis*, *Profusulina prisca* Deprat, 1912 (= *Depratina prisca* in this study) and *Eofusulina (Paraeofusulina)* at the Yarıcak section in central Taurides (Altınır and Özgül, 2001). The described zone has a diverse fusulinid taxa that include species belonging to the genus *Eostaffella*, *Millerella*, *Ozawainella*, *Neostafella*, *Pseudostaffella*, *Eoschubertella*, *Profusulinella*, *Aljutovella* and *Eofusulina*. The significant zonal marker of the Bashkirian/Moscovian boundary, *Aljutovella aljutovica*, is also founded in this assemblage (Altınır and Özgül, 2001). The Bashkirian/Moscovian boundary was studied at the Yassıpınar (southern of Hadim town) and Gölbelen (southern of Bozkır town) sections of the Hadim Nappe in a detailed biostratigraphic framework by Akbaş (2020). The Arkhangelskian substage of the Bashkirian across this boundary was defined by the occurrence of the *Tikhonovichiella tikhonovichi* and *Verella spicata* (Fig. 3). The former was found in both sections and the latter was found only in the Gölbelen section (Fig. 3). The important associated fauna of this interval includes *Pseudostaffella* ex gr. *gorskyii*, *Profusulinella pararhomboides*, *Profusulinella rhomboides*, *Solovievaia* ex gr. *nuratavensis* (Solovieva, 1977), *Depratina beppensis* (Toriyama, 1958), *Depratina prisca timanica* (Kireeva in Rauzer-Chernousova et al., 1951), *Tikhonovichiella tikhonovichi*, *Aljutovella* cf. *pseudoaljutovica* (Rauzer-Chernousova in Rauzer-Chernousova et al., 1951), *Verella normalis* Rumyantseva, 1962 and *Verella spicata* in these two sections (Akbaş, 2020). The base of the Moscovian was determined by the first occurrence of the *Solovievaia ovata* (Rauzer-Chernousova, 1938) and *Aljutovella aljutovica* in the Yassıpınar and Gölbelen sections by Akbaş (2020) (Fig. 3). In addition to the zonal markers, the significant fusulinid fauna of this interval consists of *Staffellaeformis tashliensis* (Lebedeva in Stepanov et al., 1975), *Profusulinella pseudorhomboides* Putrya and Leontovich, 1948, *Solovievaia ovata nytvica* (Safonova in Rauzer-Chernousova et al., 1951), *Solovievaia subovata*, *Depratina chernovi* (Rauzer-Chernousova in Rauzer-Chernousova et al., 1951), *Depratina paratimanica* (Rauzer-Chernousova in Rauzer-Chernousova et al., 1951), *Depratina posadai* (Villa Otero, 1995), *Depratina sitteri* (van Ginkel, 1987), *Aljutovella arrisionis* Leontovich in Rauzer-Chernousova et al., 1951, *Aljutovella arrisionis molotovensis* Safonova in Rauzer-Chernousova et al., 1951, *Aljutovella artificialis* Leontovich in Rauzer-Chernousova et al., 1951, *Aljutovella* cf. *cafirmiganica* Bensch, 1969, *Aljutovella conspecta* Leontovich in Rauzer-Chernousova et al., 1951, *Aljutovella lepida novoburasiensis* Leontovich in Rauzer-Chernousova et al., 1951, *Aljutovella postaljutovica* Leontovich in Rauzer-Chernousova et al., 1951, *Aljutovella splendida* Leontovich in Rauzer-Chernousova et al., 1951, *Aljutovella* cf. *stocklini* Leven, Davydov & Gorgij, 2006, *Aljutovella subaljutovica* Safonova in Rauzer-



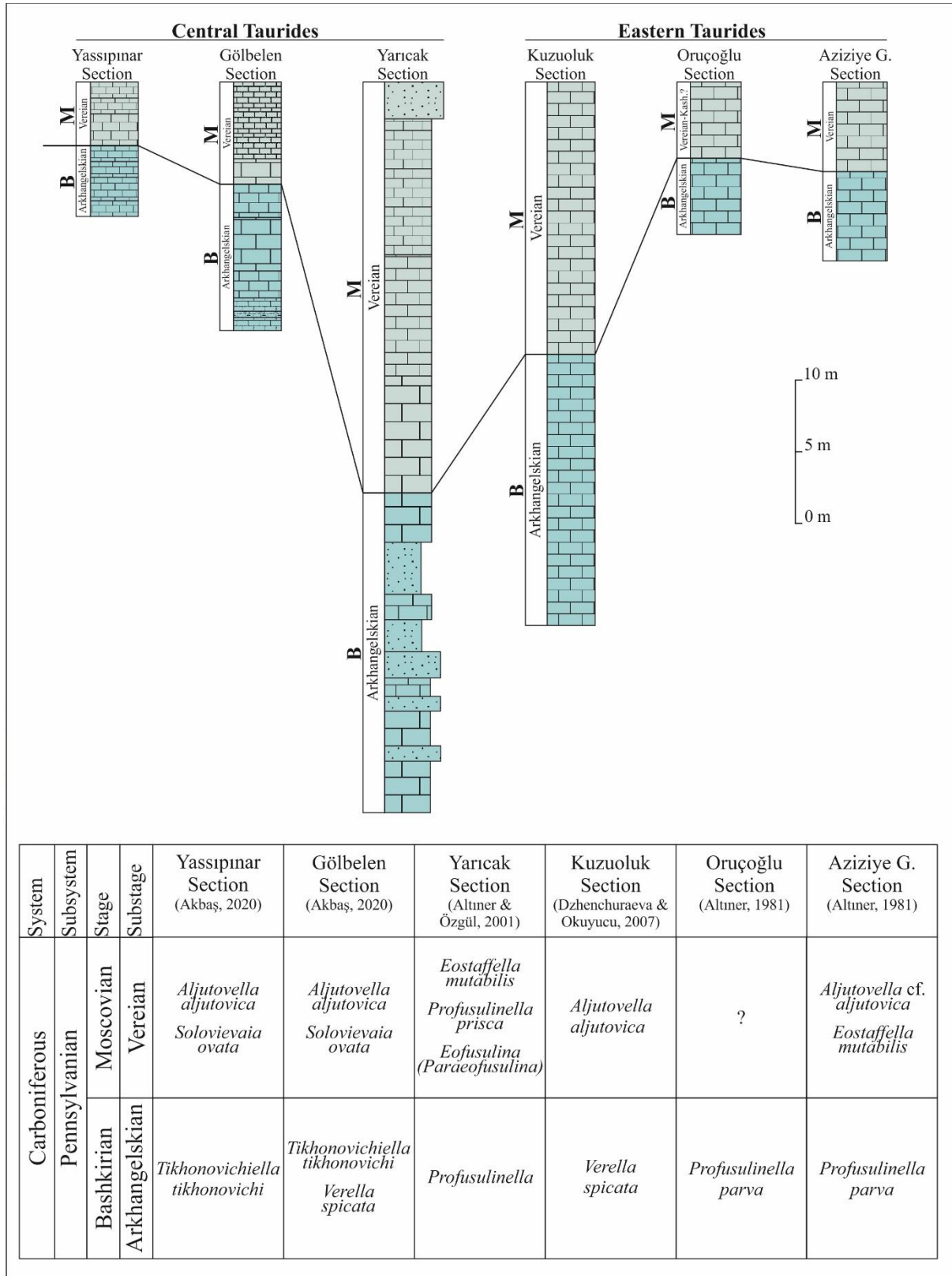
Chernousova et al., 1951 and *Aljutovella tumida* Bensch, 1969 in the Yassıpınar and Gölbelen sections of the Hadim Nappe (Akbaş, 2020).

### 3. Discussion

In past, the biostratigraphic properties of the Bashkirian/Moscovian boundary was studied at six different sections in eastern and central Tauride. When the identified fusulinid assemblages and zones in these sections are examined, there are some differences. Especially, the Bashkirian/Moscovian boundary description of the Yarıcak and Oruçoğlu sections are doubtful in Altınar (1981) and Altınar and Özgül (2001)'s studies. The fusulinid fauna recovered by Altınar (1981) and Altınar and Özgül (2001) from the eastern and central Taurides belonging to the Bashkirian is insufficient for subdivision and determination of the upper Bashkirian strata precisely.

The significant zonal markers of the upper Bashkirian, the *Tikhonovichiella tikhonovichi* and *Verella spicata*, was absent in the Oruçoğlu section of Altınar (1981). The fusulinid fauna of the Vereian and Kashirian substages of the lower Moscovian were evaluated together and the boundary between these two substages could not be encountered in the Oruçoğlu section. The marker fusulinid species for the base of the Moscovian (Vereian) stage, the *Aljutovella aljutovica*, is absent in this section. The upper Bashkirian fusulinids assemblage was very rich and diverse in the Yarıcak section studied by Altınar and Özgül (2001). The characteristic fusulinids for the upper Bashkirian of Altınar and Özgül (2001) such as, *Plectostaffella* sp. *Pseudostaffella antiqua*, *P. atiqua grandis*, *Profusulinella bona*, *P. parva*, *P. staffellaeformis*, are not the typical for this stratigraphic level and they mainly reflect lower Bashkirian assemblage (Kulagina et al., 2001; Kulagina, 2003; Leven and Gorgij, 2011; Leven, 2012; Akbas and Okuyucu, 2021). The zonal markers for the upper Bashkirian, the *Tikhonovichiella tikhonovichi* and *Verella spicata*, are absent in the Yarıcak section too. According to the Altınar and Özgül (2001) the lower Moscovian correspond to the *Eostaffella mutabilis* – *Profusulinella prisca* – *Eofusulina (Paraeofusulina)* zone. Eventhough the presence of *Aljutovella aljutovica* which is the most important marker of the Bashkirian/Moscovian boundary, it has not been cited as zonal marker for the base of the Moscovian. The rest of the reviewed sections in this study, the Kuzuoluk, Aziziye Gediği in the eastern Taurides, Yassıpınar and Gölbelen sections in the central Taurides, have similar fusulinid assemblages and more detail biostratigraphic data for the Bashkirian/Moscovian boundary. The upper Bashkirian characterized by occurrence of the *Tikhonovichiella tikhonovichi* and *Verella spicata* in all reviewed sections except the Azziye Gediği, Oruçoğlu and Yarıcak sections where this interval was defined by *Profusulinella parva*. The base of the Moscovian in the Kuzuoluk, Aziziye Gediği, Yassıpınar and Gölbelen sections has been defined by the occurrence of the *Aljutovella aljutovica* in Hadim Nappe sections. Akbaş (2020) has also suggested the occurrence of the *Solovievaia ovata* as a useful maker for this boundary in the Yassıpınar and Gölbelen sections.





**Figure 3. Lithostratigraphic columnar sections of the Bashkirian/Moscovian strata in Hadim Nappe sections and correlation of the described biozones from the Bashkirian-Moscovian boundary strata of the reviewed sections.**

#### 4. Conclusion

The Bashkirian-Moscovian successions of the Hadim Nappe composed of carbonate-dominated and rich in fusulinid foraminifera which allow to a detailed biostratigraphic control for stage boundaries. While there are some faunal differences the upper Bashkirian is characterized by *Tikhonovichiella*





*tikhonovichi* and *Verella spicata* and the base of Moscovian is defined by the occurrence of the *Aljutovella aljutovica* in most stratigraphic sections. The fusulinid assemblages of the upper Bashkirian-lower Moscovian successions in Hadim Nappe sections and the zonal markers of the Bashkirian/Moscovian boundary are also correlate well with most of the other regions of the Tethyan Realm.

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