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Remarks on the Carboniferous blocks in the Late Cretaceous Elmadağ Olistostrome from the Intra-Pontide Ocean: Biochronology of Foraminiferal assemblages from the Ankara region, central Türkiye

Melikan Akbaş[1], Cengiz Okuyucu[2,*], U. Kağan Tekin[3], Alaettin Tuncer[3], Kaan Sayit[4]

[1] Department of Geological Engineering, Konya Technical University, 42250, Konya, Türkiye; (makbas@ktun.edu.tr)
[2,*] School of Land Registry and Cadastre, Hacı Bayram Veli University, 06500, Ankara, Türkiye; (corresponding author: cengiz.okuyucu@hbv.edu.tr)
[3] Department of Geological Engineering, Hacettepe University, 06800, Beytepe, Ankara, Türkiye; (uktekin@hacettepe.edu.tr; alaettintuncer@hacettepe.edu.tr)
[4] Department of Geological Engineering, Middle East Technical University, 06800, Ankara, Türkiye; (ksayit@metu.edu.tr)

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Abstract

A detailed biostratigraphic study of the Carboniferous blocks within the Late Cretaceous Elmadağ Olistostrome exposed around Ankara city was conducted on two stratigraphic sections (Kapaklı and Sapankıran) and two isolated samples. While the Kapaklı section and two isolated samples are composed uniformly of platform limestones, the Sapankıran section is characterized predominantly by sandstones with platform limestone interlayers. Based on Foraminiferal assemblages, one isolated sample (21-EL-41) provides the oldest age (middle Viséan), whereas the other isolated sample (21-EL-06) yields an early Serpukhovian age. Three local foraminiferal biozones are defined in the Serpukhovian Kapaklı section: the *Neoarchaediscus postrugosus – Biseriella parva* Assemblage Zone, the *Eostaffellina decurta* Zone and the *Eostaffellina paraprotvae* Zone. The date recovered in this study from the smaller foraminifers and fusulinids implies that the youngest age (late Early–late Bashkirian) within the Carboniferous blocks is from the Sapankıran section. According to the correlation with nappes (e.g., Hadim Nappe, Bolkar Dağı Nappe, and Beyşehir–Hoyran nappes) originating from the Izmir–Ankara–Erzincan Ocean (southern branch of Northern Neotethys), the upper Lower-upper Bashkirian strata are characterized by similar lithology and a common foraminiferal assemblage in both the Intra-Pontide and Izmir–Ankara–Erzincan (Hadim Nappe) units. The Serpukhovian strata examined in this study are composed of carbonates without any siliciclastic input, while this interval corresponds to siliciclastic-dominated rock units in the Hadim Nappe. Additionally, the Middle–Upper Pennsylvanian deposits within the Carboniferous blocks of the Intra-Pontide sequences could not be detected in this study, as it has been observed in the Bolkar Dağı and Beyşehir-Hoyran nappes.

Keywords: Foraminifera, Carboniferous, Elmadağ Olistostrome, Intra-Pontide Ocean, Neotethys

1. INTRODUCTION

The current tectonic architecture of Anatolia has been achieved through the obliteration of the Tethyan oceans and the subsequent terrane amalgamation (ŞENGÖR & YILMAZ, 1981; YILMAZ, 1990; GÖNCÜOĞLU et al., 1997; OKAY & TÜYSÜZ, 1999; STAMPFLI, 2000; GÖNCÜOĞLU et al., 2000; GÖNCÜOĞLU, 2010) (Fig. 1). The "Tethyan oceans" include two major oceanic domains; Palaeotethys and Neotethys. Palaeotethys is the older one, believed to have existed between the Middle/Late Palaeozoic and the Early Mesozoic (ŞENGÖR, 1979; ŞENGÖR et al., 1984; STAMPFLI & BOREL, 2002). This oceanic domain was consumed in the Late Triassic/Early Jurassic, resulting in the Cimmeride Orogeny (ŞENGÖR et al., 1984). The opening of the younger Neotethys, was initially thought to have occurred in the Liassic, nearly coeval with the closure of Palaeotethys (GÖRÜR et al., 1983). However, it was later revealed that the Izmir–Ankara–Erzincan (IAE) Ocean, one of the Northern Neotethyan branches, was already a mature ocean well before the Liassic, as displayed by the Middle–Late Triassic intra-oceanic subduction magmatism (SAYİT et al., 2015, 2017, 2020), and Early/Middle Permian rifting (TEKİN et al., 2019). A similar issue can also be valid for the other Northern Neotethyan branch, namely the Intra-Pontide (IP) Ocean, which appears to have rifted before the Triassic (TEKİN et al., 2025).

Traces of the Cimmeride Orogeny in Anatolia were sought for many years within the Karakaya Complex. BİNGÖL et al. (1975) were the first to coin the term "Karakaya Formation" for the very low-grade metamorphic, rift-related sequence, made up of limestone blocks, clastic deposits, and basalts. Conversely, TEKELİ (1981) described a similar assemblage as a subduction/accretion complex, which they called the "North Anatolian Mélange". ŞENGÖR et al. (1984) also adopted the mélange character of the unit and subsequently introduced the term "Karakaya Complex". In terms of the Tethyan context, while some studies regard the Karakaya Complex as fragments of Paleotethys itself, others believe it to represent a continental back-arc that opened behind Palaeotethys (e.g., ŞENGÖR & YILMAZ, 1981; OKAY et al., 1990, 1991; PICKETT & ROBERTSON, 1996; GÖNCÜOĞLU et al., 2000; SAYİT et al., 2010). Another idea is that the Karakaya Complex includes both Palaeotethyan and rift-derived components (SAYİT & GÖNCÜOĞLU, 2013).

The Karakaya Complex stretches along an E–W trending belt, covering a huge area in northern Türkiye. OKAY & GÖNCÜOĞLU (2004) suggested a structural division of the Karakaya Complex into the Lower and Upper Karakaya complexes. According to this subdivision, the Upper Karakaya Complex is regarded as an unmetamorphosed olistostromal unit made up of blocks of limestone, clastic deposits, and basalts. The Lower Karakaya Complex, on the other hand, is thought to be a metamorphic unit, the bulk of which is characterized mainly by the Nilüfer Unit (*sensu* OKAY et al., 1990, 1991). However, SAYİT et al. (2010) implied that all mafic lithologies within the Karakaya Complex, whether metamorphic or not, are of comparable age and origin, thus raising questions about the unit's classification based on metamorphism (SAYİT & GÖNCÜOĞLU, 2013).

For about 50 years, it was believed that the Lower and Upper Karakaya complexes are pre-Jurassic in age (e.g., KAYA & MOSTLER, 1992; AKYÜREK et al., 1984; OKAY & GÖNCÜOĞLU, 2004). Regarding the Lower Karakaya Complex, Early and Middle Triassic conodont ages were obtained from the marbles intercalated with metabasites within the Nilüfer Unit in northwest Anatolia (KOZUR et al., 2000; KAYA & MOSTLER, 1992). In the Ankara region, an Early Triassic foraminiferal age was determined from carbonate bands intercalated in the low-grade metamorphic detrital series (AKYÜREK et al., 1979). In contrast to these Triassic ages, some blueschist-facies lithologies from the Eskişehir region (central Anatolia), once thought to be Upper Triassic as a whole (OKAY et al., 2002), were dated as the Upper Jurassic (OKAY et al., 2020). Therefore, this new finding excluded these rocks from the original definition of the Karakaya Complex.

The inferred pre-Liassic age of the Upper Karakaya Complex mostly comes from limestone and limestone-bearing basaltic blocks from the Ankara (central Anatolia) and Biga (western Anatolia) peninsula, which have yielded Middle to Late Triassic ages (e.g., BİNGÖL et al., 1975; KAYA, 1991; SAYİT & GÖNCÜOĞLU, 2009). In addition to these, a Spathian (Early Triassic) age was obtained from a pelagic cherty limestone block within the same unit around Gökçehöyük village (south of Ankara), based on the conodont and radiolarian fauna (TEKİN et al., 2021). A chert layer interbedded with the clastics in the Ortaköy area (NE of Ankara), was found to be of Carnian (Late Triassic) age based on the radiolarian assemblage (SAYİT et al., 2011). After many years of acceptance of the Triassic age, TEKİN et al. (2025) extracted Jurassic and Cretaceous ages from a part of the so-called Upper Karakaya Complex near Kutludüğün village (East of Ankara), corresponding to the Elmadağ Olistostrome by TEKİN et al. (2024) in the south of Ankara city. The discovery of these post-Triassic ages from the Elmadağ Olistostrome has been very critical, since it has reshaped the view of the Karakaya Complex in the context of Palaeotethys and the Sakarya Terrane.

While the limestone blocks of Carboniferous–Permian age from the Elmadağ Olistostrome have been examined in several studies, the most comprehensive examination to date was carried out by LEVEN & OKAY (1996) on the Hodul and Çal units (western Anatolia). These units, which are partly or entirely olistostromal in character, were previously assumed to be parts of the Upper Karakaya Complex (now the Elmadağ Olistostrome). However, no detailed study has ever been done on the limestone blocks of Carboniferous–Permian age in central Anatolia, which makes it difficult to link the western and central sectors. Also, it is noteworthy that these limestone blocks were previously evaluated within the framework of

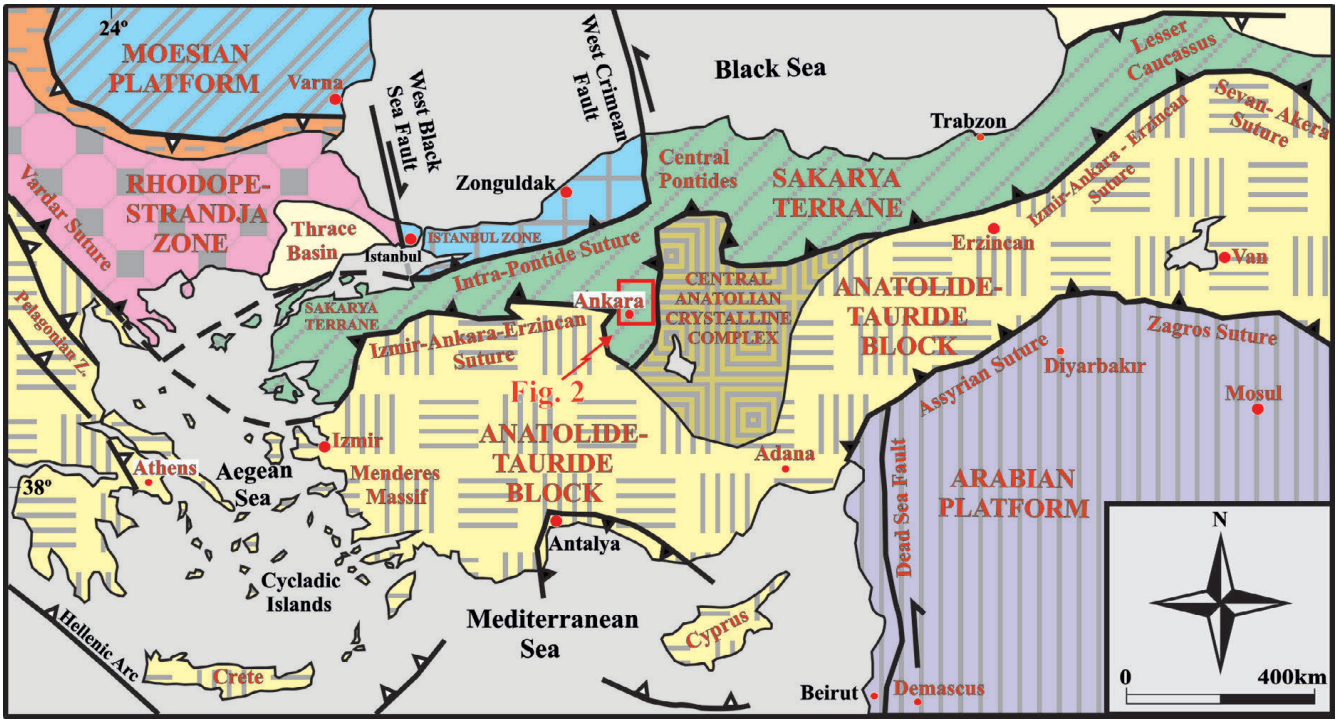

Figure 1. Tectonic map of Türkiye and its surroundings with major suture zones/terranes and location of the studied region around Ankara city (slightly revised after OKAY & TÜYSÜZ, 1999; OKAY & GÖNCÜOĞLU, 2004).

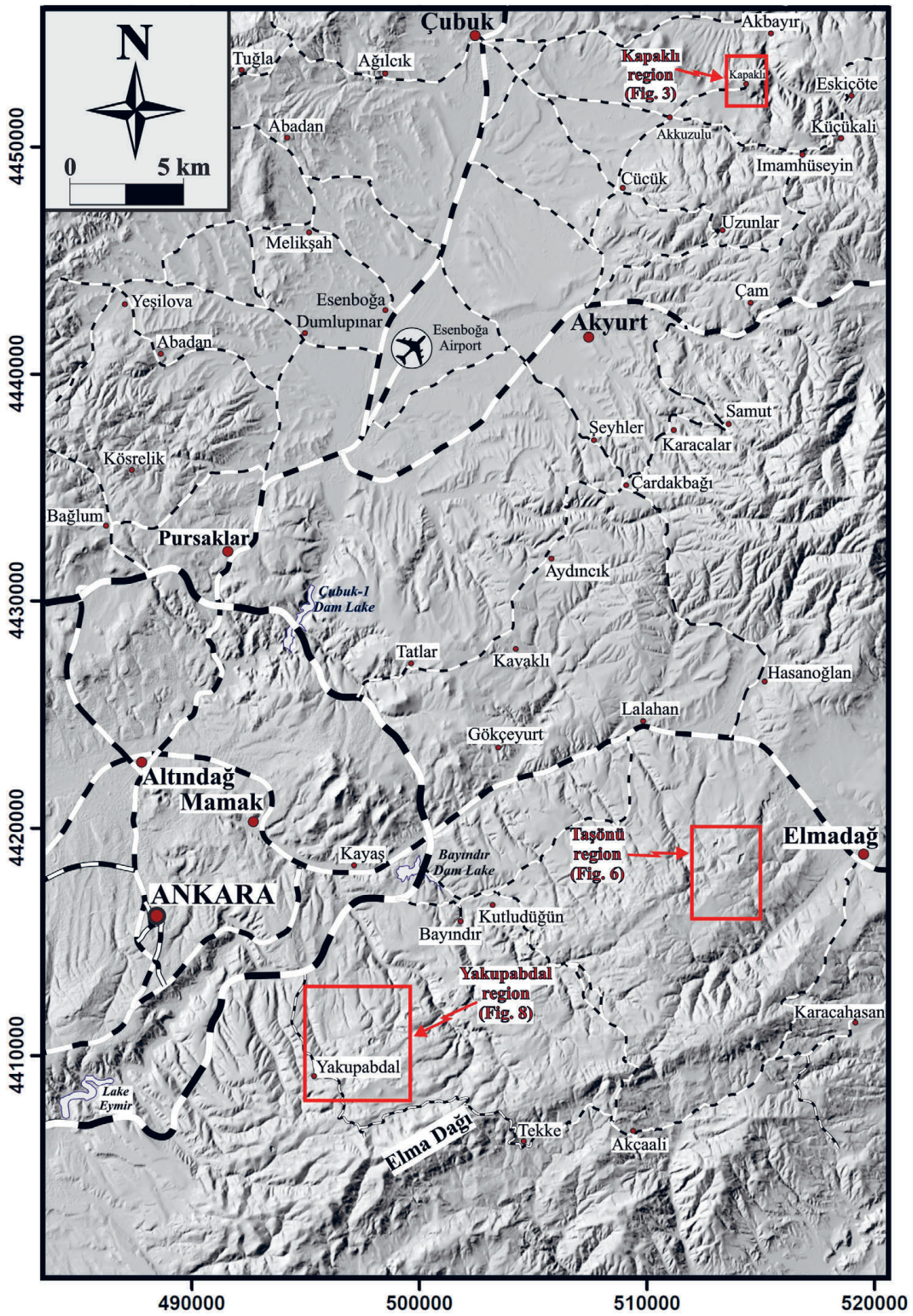

Figure 2. Location map showing the distribution of the studied regions (Kapaklı, Taşönü, and Yakupabdal) around Ankara city.

Palaeotethys, not Neotethys. Therefore, in this study, we present a detailed examination of the blocks from the Elmadağ Olistostrome, exposed in the Kapaklı region (NE of Ankara city), and the Taşönü region (East of Ankara city) and Yakupabdal village (SE of Ankara city) (Fig. 2). By doing this, we aim to (i) date benthic foraminifera from platform limestones and document their foraminiferal assemblages, and (ii) correlate the rock units and their faunal assemblages in the studied regions to those previously described in Anatolia.

2. GEOLOGICAL FRAMEWORK

The Ankara region is confined within the Sakarya Composite Terrane (GÖNCÜOĞLU et al., 1997), between the remnants of the northern Neotethyan branches delineated by the Intra-Pontide (IP) and Izmir–Ankara–Erzincan (IAE) suture zones (Fig. 1). Numerous studies have focused on the geological history of Ankara city and its surroundings since the early 1900's (e.g., PHILIPSON, 1919; CHAPUT, 1931; EROL, 1956;

BOCCALETTI et al., 1966; NORMAN, 1975; BATMAN et al., 1978; ÜNALAN, 1981; ÇAPAN et al., 1983; AKYÜREK et al., 1984; KOÇYİĞİT, 1991; ROJAY et al., 2001; BORTOLOTTI et al., 2013; SARIFAKIOĞLU et al., 2017; OKAY et al., 2022; ROBERTSON et al., 2023). Among these, two studies, EROL (1956) and AKYÜREK et al. (1984), are particularly important as they offer a comprehensive summary of the geological features for the vast proportion of the Ankara region and its surroundings, including the study area.

Four major geological rock units were identified in the Ankara region by EROL (1956): a) the Palaeozoic "Dikmen Graywacke Serie", b) the Mesozoic "Elma Dağı Exotic-Block Series", c) the Mesozoic "Serpentine-Radiolarite Series" and d) the Santonian (Upper Cretaceous) to Quaternary "Cover Units".

These rock units are summarized below.

(a) The Palaeozoic Dikmen Graywacke Serie: This unit, first identified by CHAPUT (1931) as the "Old Elma Dağ Serie", consists mainly of non-metamorphic to low-grade metamorphic siliciclastics and subordinate schists, with rare carbonates/chert interlayers at the base and basic volcanic breccias at the top. The Dikmen Greywacke Serie was named after Dikmen village to the south of Ankara city centre (EROL, 1956). While AKYÜREK et al. (1984) renamed this unit as the Emir Formation as part of their Ankara Group, in this study, we adopted the name "Dikmen Graywacke (DG)" following EROL (1956) and TEKİN et al. (2025) and it was dated as Middle Triassic by TEKİN & TUNCER (2024).

(b) The Mesozoic Elma Dağı Exotic-Block Series: This unit was originally described in the Elma Dağı region (SE Ankara) as the Elma Dağı Exotic-Block Series (=Boulder Bed Series) by EROL (1956). AKYÜREK et al. (1984) later named this unit the Elmadağ Formation, which contains various blocks in a clastic matrix. The name Elmadağ Olistostrome (EO) has been used for this unit in this study, as in TEKİN et al. (2025). The EO is mostly made up of limestone, chert and graywacke blocks within a Coniacian (Late Cretaceous) flysch matrix, including red, yellow, and white claystone, conglomerate, sandstone, and marl (TEKİN et al., 2024, 2025).

(c) The Mesozoic Serpentine-Radiolarite Series: This unit is composed of the ophiolitic mélange originating from the accretionary prism of the Neotethyan IAE Ocean.

(d) The Santonian (Late Cretaceous) to the Quaternary cover rock units consisting of clastic and carbonate sedimentary rocks and volcanics.

3. MATERIALS AND METHODS

A total of 36 randomly oriented thin sections were prepared from the collected limestone samples for palaeontological analyses. The thin sections prepared are typically about 30 micrometres thick, mounted on a glass slide for microscopic observation under transmitted or polarized light. A Zeiss Primo Star palaeontological analyses transmitted light microscope was used for examination of the thin sections, and a Mshot MD50 digital microscope camera for taking photomicrographs of the foraminifers.

4. LITHOSTRATIGRAPHIC CHARACTERISTICS OF STRATIGRAPHIC SECTIONS AND ISOLATED SAMPLES

This study was carried out in three different regions (i.e., Kapaklı, Taşönü, and Yakupabdal) located to the north and east of Ankara city (Fig. 2). Isolated sample 22-EL-41 and samples of the Kapaklı section were collected from the Kapaklı region (Fig. 2). The isolated sample 21-EL-06 was collected from the Taşönü region, while the samples along the Sapankıran section were retrieved from the Yakupabdal region (Fig. 2).

4.1. The Kapaklı Region

This region, located NE of Ankara city, includes outcrops of different blocks (e.g., platform limestone blocks of Early Carboniferous and Middle to Late Triassic ages) within the siliciclastic matrix of the Late Cretaceous Elmadağ Olistostrome (Figs. 2, 3, 4a–b). This olistostrome was covered by Tertiary basic volcanics in many parts (Figs. 3, 4a–b). A total of twelve samples were collected from this region, eleven from the Kapaklı section, and one as an isolated sample (21-EL-41).

4.1.1. Sample 21-EL-41

This sample was collected from the SE of Kapaklı village (at Çankırı H30-d2 quadrangle sheet, coordinates: 5 14 514 E / 44 52 392 N; Fig. 3, 4b–c; Table 1). It was derived from a relatively small block (ca 120 cm width, 260 cm length) composed of grey-coloured and thick-bedded limestone in a siliciclastic matrix of the Elmadağ Olistostrome (Figs. 3, 4b–c). Based on the benthic foraminifera, a middle Viséan (Mississippian) age was assigned to this block (Table 1). One of the mega-blocks of Carboniferous age is situated approximately 2 metres north of this sample (Fig. 4b–c), where the Kapaklı section was measured.

4.1.2. The Kapaklı Section

Apart from the small block where sample 21-EL-41 was collected, a mega-block approximately 500 – 600 m in length and 30 m wide is exposed on two sides of Canak creek (Figs. 3, 4a–b), close to the east of Kapaklı village. The samples were collected on the Kapaklı section from this mega-block (at the Çankırı H30-d2 quadrangle sheet, between 5 14 514 E / 44 52 394 N and 5 14 520 E / 44 52 494 N coordinates; Figs. 3, 4b; Table 1). The name of the section was derived from Kapaklı village, and the rock units of this section are uniformly composed of grey-coloured and thick-bedded platform carbonates totalling 30m in thickness. A total of eleven samples (22-KPK-4 to 22-KPK-14) were collected along this section for benthic foraminiferal determination (Figs. 4b–e, 5). Based on the abundant foraminiferal fauna, a Serpukhovian (Mississippian) age is assigned to this section (Table 1; Fig. 5)

4.2. Taşönü Region

The Taşönü region is situated to the west of the town of Elmadağ (east of Ankara) and has been named after the Taşönü creek in this area (Figs. 2, 6). In this region, the Middle Triassic Dikmen Graywacke (TEKİN & TUNCER, 2024) is unconformably overlain by the Coniacian Elmadağ Olistostrome with blocks

of different lithologies (e.g., clastics with phosphate nodules of ?Early Carboniferous age, Carboniferous platform limestones, Permian platform limestones, basic volcanics alternating with detrital limestone and chert with spiculite/radiolarians of Anisian–late Ladinian (Middle Triassic) age, and platform limestones of possible Jurassic age; Fig. 6). One sample (06-EL-06) from the limestone block exposed to the north of this region was studied in detail in this study (Fig. 6).

4.2.1. Sample 21-EL-06

This sample was retrieved from a small block (ca. 26 m length and 17 m width) to the north of the Taşönü, region, located southeast of Dedeardıç hill (at the Kırşehir I30-a2 quadrangle sheet, coordinates: 5 14 078 E / 44 19 740 N; Figs. 6, 7a; Table 1). This sample was derived from the grey- to beige-coloured and thick-bedded limestones with brown-coloured secondary chert nodules (Fig. 7b–c). Based on the benthic foraminiferal fauna, the age of the sample is assigned to the early Serpukhovian (Mississippian) (Table 1).

4.3. Yakupabdal Region

This region is located northeast of Yakupabdal village and was named after this village (Figs. 2, 8). The Middle Triassic Dikmen Graywacke is unconformably overlain by the Coniacian Elmadağ Olistostrome with blocks of different lithologies (e.g., clastics with phosphate nodules of ?Early Carboniferous age, sandstones with limestone intercalations of Late Carboniferous age, Permian detrital and platform limestones, alternating basic volcanic and platform limestone of Anisian to Ladinian (Middle Triassic) age, pelagic limestone of possible Triassic age and platform limestones of possible Jurassic age) in this region (Fig. 8). The Sapankıran section was measured from the sequence of limestone interlayers in sandstones (Table 1).

4.3.1. The Sapankıran Section

One of the mega-blocks studied here (ca. 2.5 km length and 0.3 km width) extends NE to SW to the NE of Yakupabdal village and contains benthic foraminiferal assemblages (Fig. 8). The Sapankıran section is located southeast of Sapankıran hill in the Yakupabdal region (at Ankara I29-b3 quadrangle sheet, between 4 98 470 E / 44 11 650 N and 4 98 426 E / 44 11 658 N coordinates; Figs. 8, 9, 10a; Table 1) and was named after this hill. This section is mainly characterized by yellowish grey- to brown-coloured, medium- to thick-bedded sandstones with grey- to beige-coloured, thick-bedded platform limestone interlayers (Figs. 9, 10b–d). The total thickness of the section is about 28.9 metres, and a total of five samples (22-SAP-01 to 22-SAP-05) were collected from the thick-bedded limestone

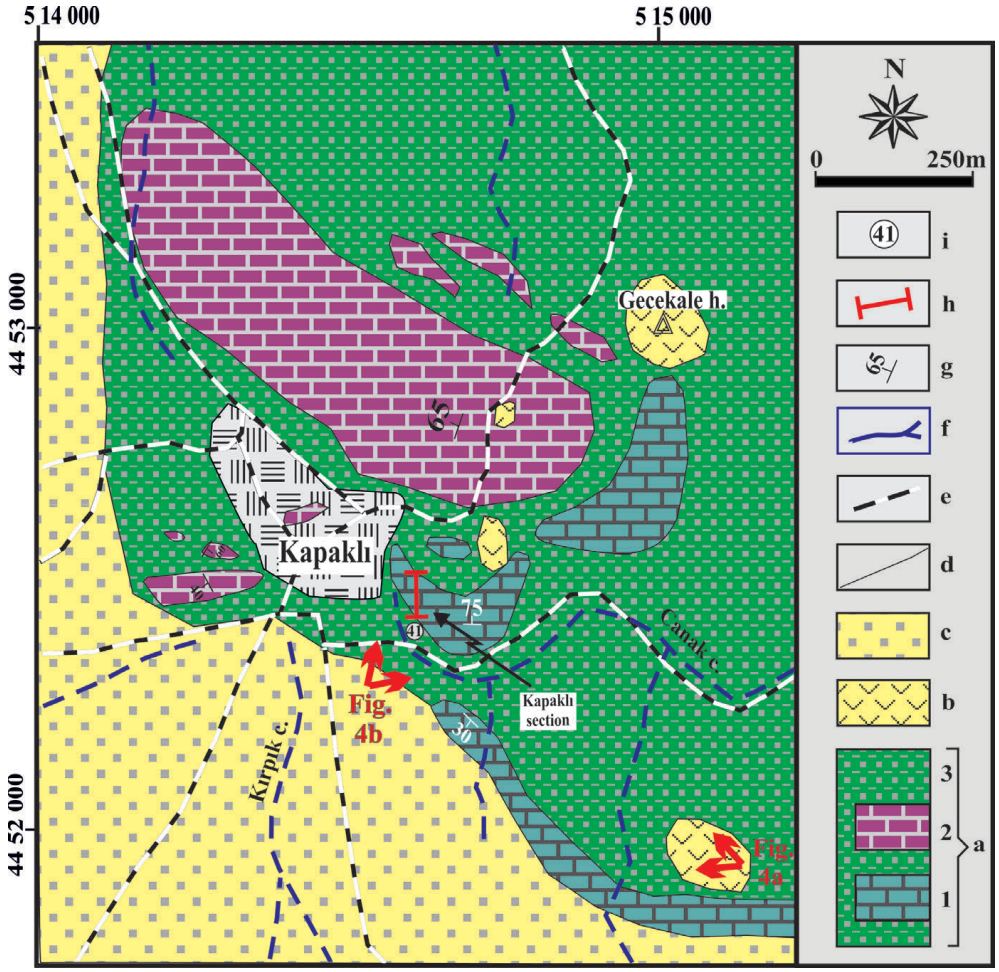

Figure 3. Geological map of the region around Kapaklı village to the NW of Ankara city. Legend: **a** – Coniacian Elmadağ Olistostrome: **1** – Blocks of Early Carboniferous platform limestone, **2** – Blocks of Triassic platform limestone, **3** – Undifferentiated siliciclastic matrix of the Elmadağ olistostrome, mainly sandstone; **b** – Tertiary basic volcanics; **c** – Undifferentiated Tertiary–Quaternary deposits (mainly clastics, volcanics, and volcaniclastics); **d** – Stratigraphic contact; **e** – Main roads; **f** – Drainage system; **g** – Dip and strike; **h** – Section place; **i** – Location of the sample 21-EL-41.

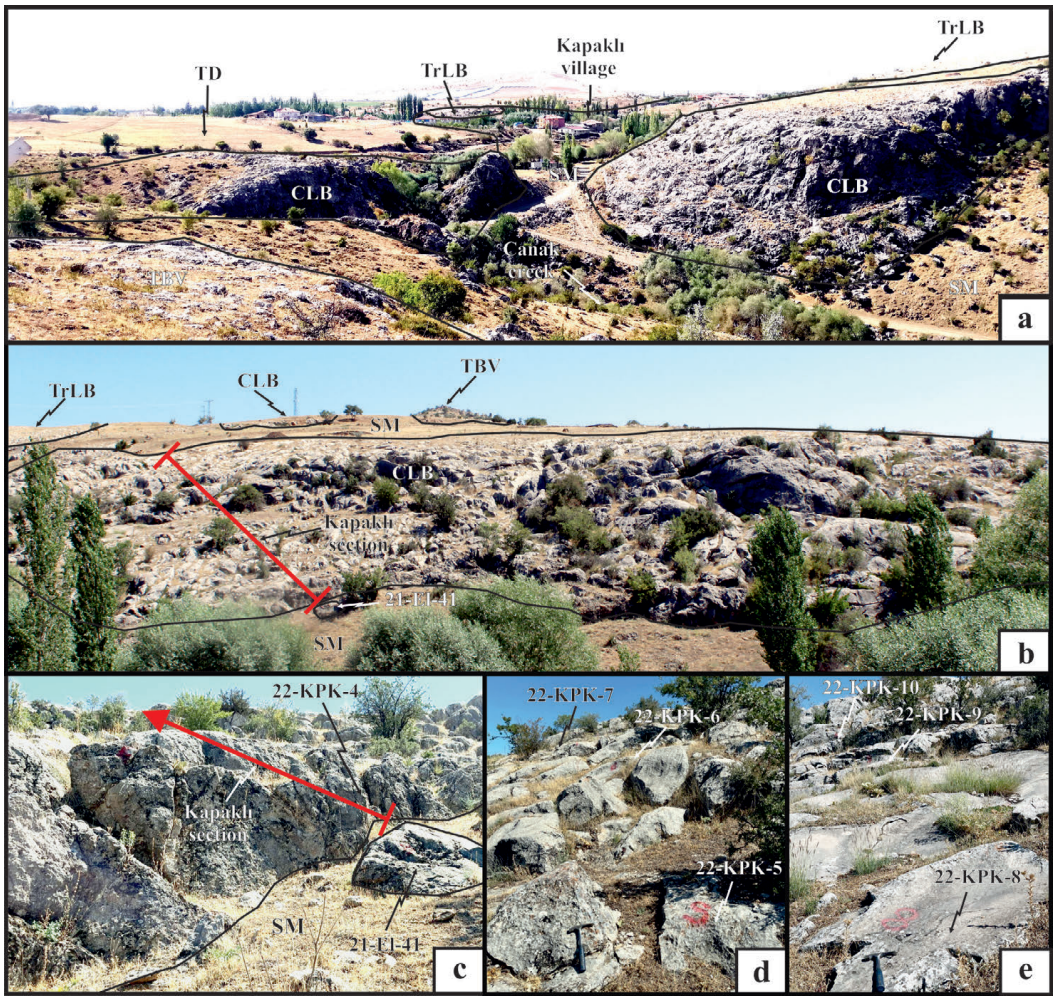

Figure 4. Field photographs from the Kapaklı region to the NW of Ankara: (**a**) General view of the Kapaklı region showing the Carboniferous limestone block (CLB) on both sides of the Canak creek and Triassic limestone blocks (TrLB) in the siliciclastic matrix (SM) of the Elmadağ Olistostrome overlain/intruded by Tertiary deposits (TD) and Tertiary basic volcanics (TBV) (view from SE to NW, for location see Fig. 4); (**b**) General view showing the locations of sample 21-EL-41 and the Kapaklı section taken from the Carboniferous limestone block (CLB) within the siliciclastic matrix (SM) of the Elmadağ Olistostrome (view from SW to NE, for location see Fig. 4). To the north, blocks of Triassic limestone block (TrLB), other Carboniferous limestone block (CLB) and intruded Tertiary basic volcanic (TBV) are also visible at the back; (**c**) View showing the relationship between a small block composed of grey- to beige-coloured, medium- to thick-bedded limestone within the siliclastic matrix (SM) of the Elmadağ Olistostrome from where sample 21-EL-41 was derived, and a mega-block of Carboniferous limestone (CLB) where the Kapaklı section was measured; (**d**) View from the central part of the Kapaklı section taken from a grey- to beige-coloured, medium- to thick-bedded limestone mega-block of Carboniferous age where samples 22-KPK-5, 22-KPK-6, and 22-KPK-7 were retrieved; (**e**) View of the samples 22-KPK-8, 22-KPK-9, and 22-KPK-10 from the central to upper parts of the Kapaklı section.

interlayers for benthic foraminiferal determinations. Benthic foraminiferal assemblages from three positive samples (22-SAP-01, 22-SAP-02, and 22-SAP-05) reveal a late Early-late Bashkirian (Pennsylvanian) age (Fig. 9; Table 1).

5. FORAMINIFERAL BIOCHRONOLOGY

Descriptions of benthic foraminiferal assemblages from sample 21-EL-41 of middle Viséan age, sample 21-EL-06 of early Serpukhovian age, samples from the Kapaklı section of Ser-

Table 1. Quadrangles, coordinates, lithological characteristics, dating assemblages, and ages of the individual samples and samples from sections retrived from blocks in the Elmadağ Olistostrome.

Sample Number/ Section	Quadrangles/ Coordinates	Type of Lithology	Dating	
			Age	Period
Sapankıran section	Ankara I29-b3 4 98 470 E / 44.11 650 N 4 98 426 E / 44 11 658 N	Platform limestone interlayers in sandstone	late Bashkirian	Carboniferous
Kapaklı section	Çankırı H30-d2 5 14 514 E / 44 52 394 N 5 14 520 E / 44 52 494 N	Platform limestone	Serpukhovian	
Sample 21-EL-06	Kırşehir I30-a2 5 14 078 E / 44 19 740 N	Platform limestone	early Serpukhovian	
Sample 21-EL-41	Çankırı H30-d2 5 14 514 E / 44 52 392 N	Platform limestone	middle Viséan	

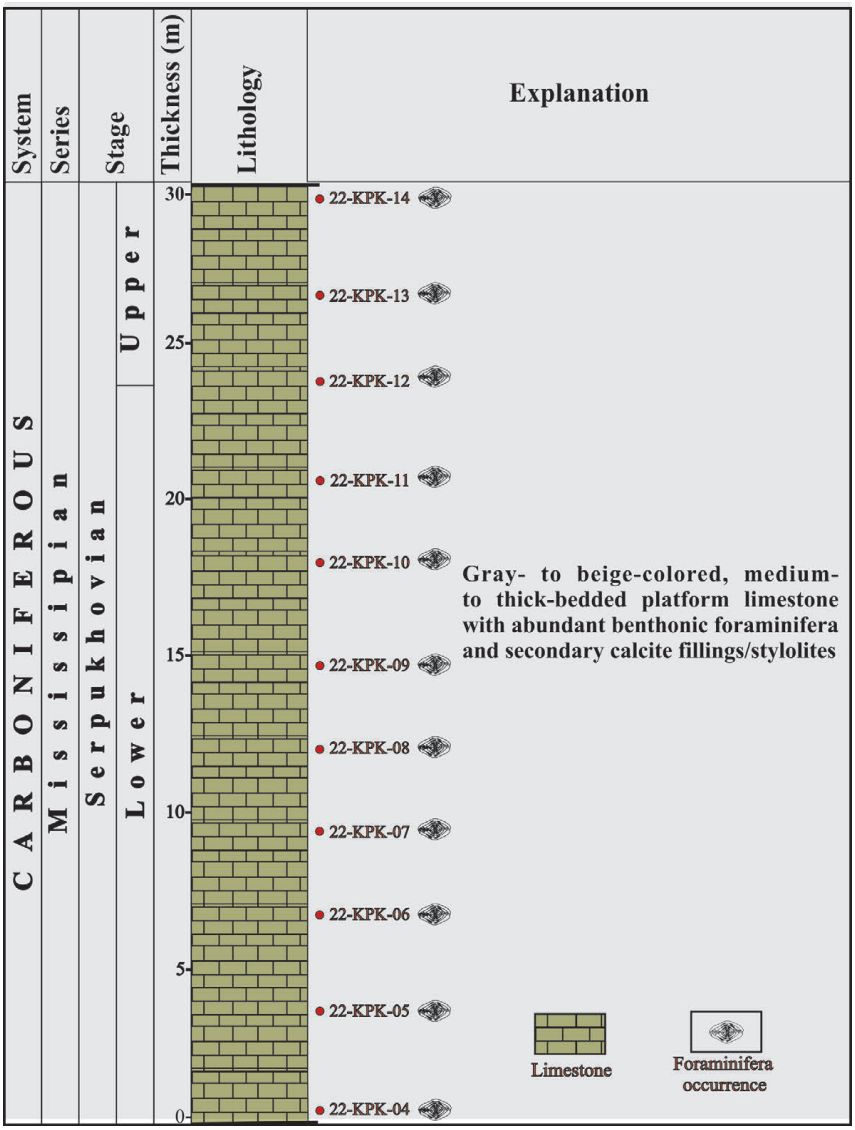

Figure 5. Log of the Kapaklı section and sampling points.

pukhovian age, and samples from the Sapankıran section of late Early–late Bashkirian age are presented as follows in chronological order (Table 1).

5.1. Sample 21-EL-41

The poor foraminiferal assemblage of this sample includes *Dainella callosa* VDOVENKO in BRAZHNIKOVA & VDOVENKO, 1973, *Pojarkovella*? sp. 1, *Haplophragmella* sp. 1 and *Millerella* sp. 1 (Fig. 11A–D). *Dainella callosa* was described for the first time by VDOVENKO (in BRAZHNIKOVA & VDOVENKO, 1973) from the uppermost Tournaisian – lowermost Viséan strata of the Donbas Basin. Later, it was reported from the uppermost Tournaisian deposits from the Alborz Basin, northern Iran (ABADI et al., 2017) and southern Urals (KULAGINA et al., 2018). Although this species is not well-known in the literature, it was described in Türkiye's lower Viséan strata from the Zonguldak Carboniferous Basin (DİL, 1976) and the middle Viséan strata of the Hadim Nappe, central Taurides (AKBAŞ, 2024). While the stratigraphic range of the genus *Pojarkovella* is mainly known from the middle Viséan to the late Serpukhovian, it is very common in the late Middle to late Viséan (HANCE et al., 2011; CÓZAR et al., 2014; VACHARD et al., 2016). Of the other taxa defined in sample 21-EL-41, *Haplophragmella* (=*Mstinia*) was described from Viséan to lowermost Serpukhovian deposits (see brief review by PILLE, 2008) in previous studies. Based on these foraminiferal taxa, the age of sample 21-EL-06 is suggested to be middle Viséan (Middle Mississippian) (Table 1).

5.2. Sample 21-EL-06

The foraminiferal fauna of this sample is poor and includes only *Hemidiscopsis muradymica* (KULAGINA in KULAGINA et al., 1992), *Eotuberitina* sp. and *Radiosphaera* sp. (Fig. 11E-H). *Hemidiscopsis muradymica,* with a rather short range, was described for the first time by KULAGINA et al. (1992) from the Serpukhovian-lowermost Bashkirian strata in the southern Urals. Later, it has been reported from the Viséan–Serpukhovian boundary interval and accepted by many researchers as a potential marker for this time interval (NIKOLAEVA et al., 2009, 2020; PAZUKHIN et al., 2010; CÓZAR et al., 2015; VACHARD et al., 2016). The other taxa (*Eotuberitina* sp. and *Radiosphaera* sp.) recovered from this sample have a long

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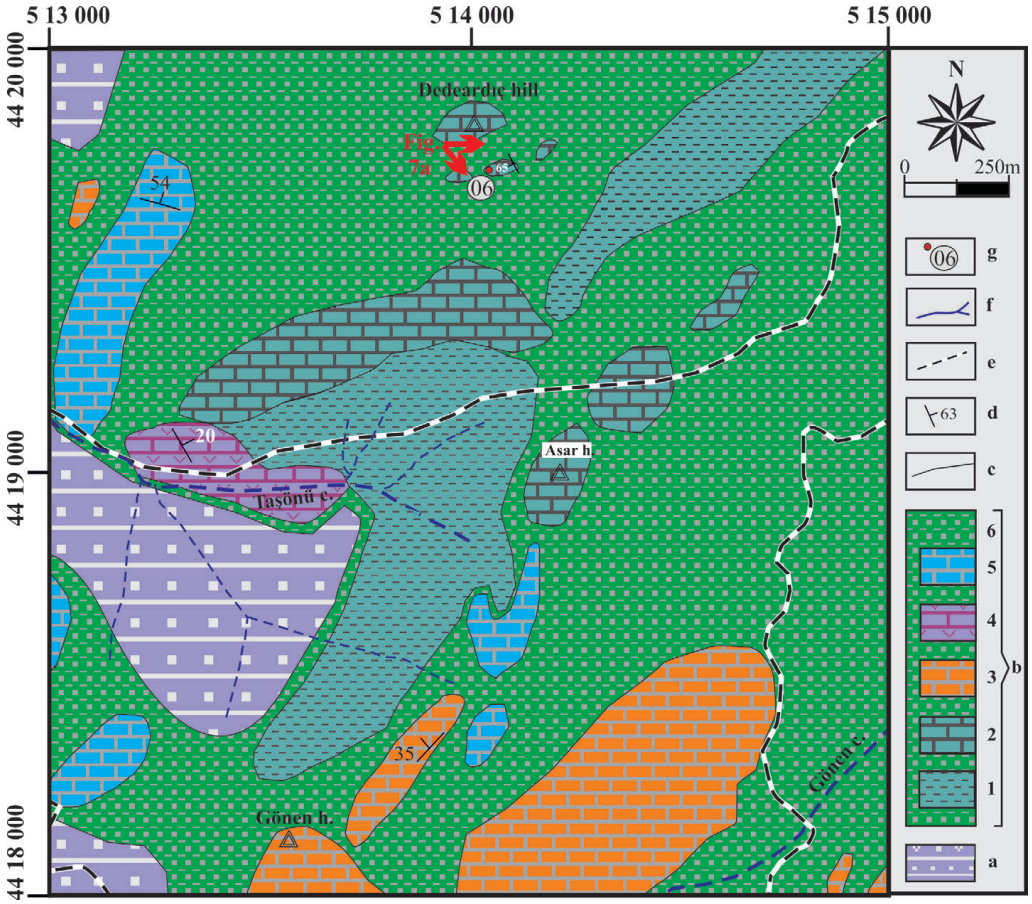

Figure 6. Geological map of the region around the Taşönü region showing the place of sample 21-EL-06 to the SE of the Dedeardıç hill. Legend: **a** – The Middle Triassic Dikmen Graywacke composed of siliciclastic and volcaniclastic/volcanic breccia; **b –** Late Cretaceous Elmadağ Olistostrome composed of foreland flysch deposits of the Intra-Pontide Ocean: **1 –** Blocks of clastics with phosphate nodules of ?Early Carboniferous age, **2 –** Blocks of Carboniferous platform limestone, **3 –** Blocks of Permian platform limestones, **4 –** Blocks of alternating basic volcanic, detritial limestone, and spiculite/radiolarian of Anisian-late Ladinian (Middle Triassic) age, **5 –** Platform limestones of possible Jurassic age, **6 –** Late Cretaceous carbonaceous clastic/clayey carbonate and siliciclastic matrix of the Elmadağ Olistostrome; **c –** Stratigraphic contact; **d –** Dip and strike; **e –** Main roads; **f –** Drainage system; **g –** Location of the sample 21-EL-06 (after TEKİN & TUNCER, 2024).

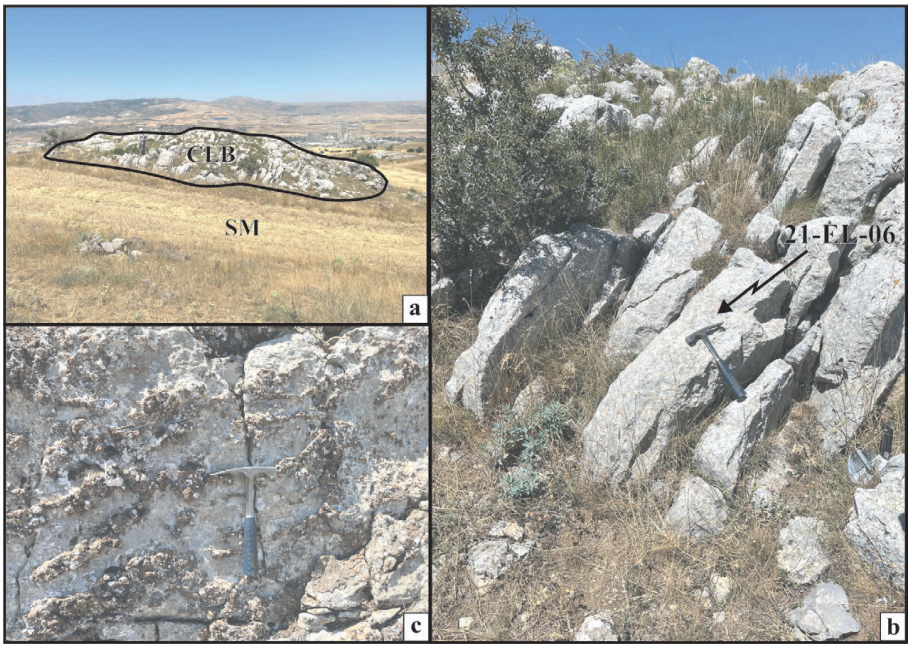

Figure 7. Field photographs of the early Serpukhovian (Carboniferous) limestone block located to the SE of Dedeardıç hill in the Taşönü region to the west of Elmadağ city: (**a**) General view from the Carboniferous limestone block (CLB) within the siliciclastic matrix (SM) of the Elmadağ Olistostrome, where sample 21-EL-06 was collected (for location see Fig. 6); (**b**) Detailed view from the block composed of grey-coloured and thick-bedded limestone of early Serpukhovian age, where sample 22-EL-06 was retrieved; (**c**) Detailed view from the brown-coloured secondary chert nodules within the limestone in this block.

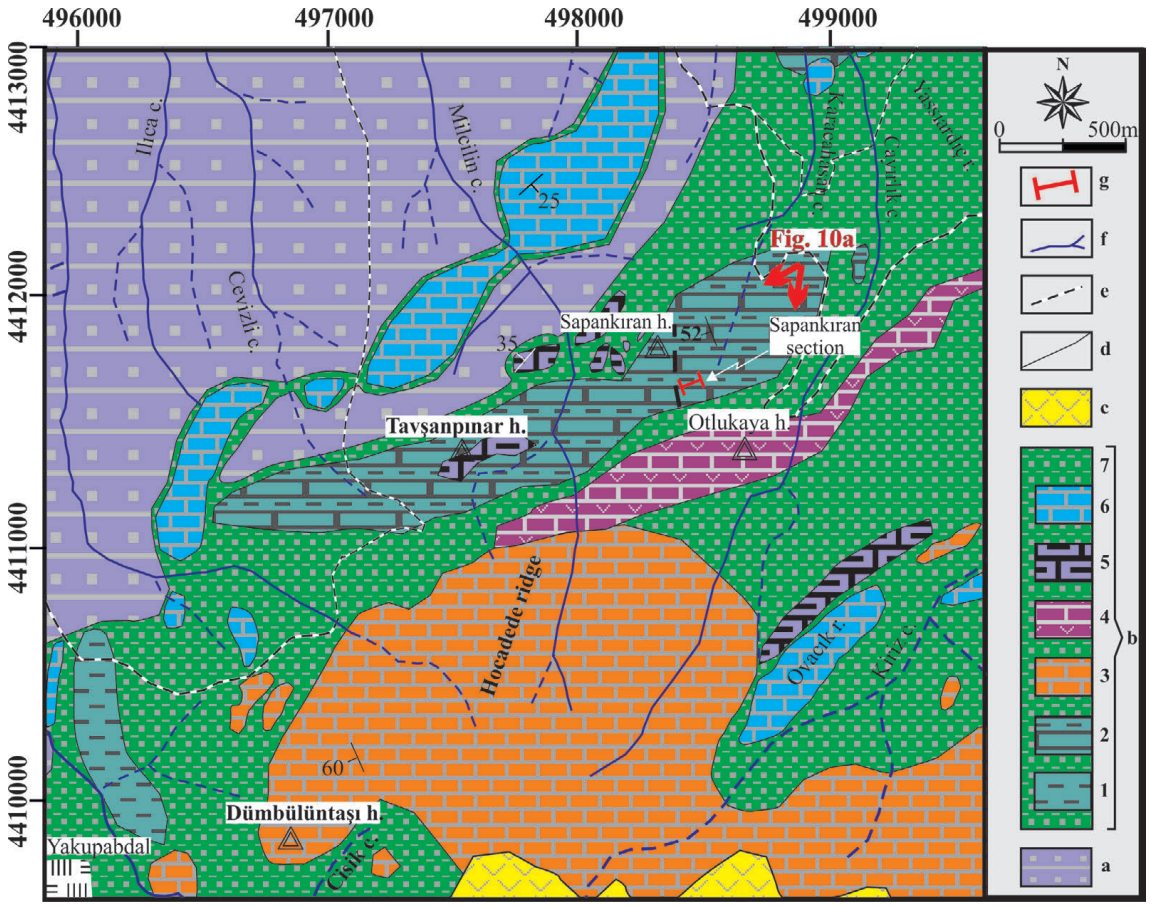

Figure 8. Geological map of the region to the NE of Yakupabdal village showing the location of the Sapankıran section. Legend: **a –** The Middle Triassic Dikmen Graywacke composed of siliciclastic and volcaniclastic/volcanic breccia; **b –** Late Cretaceous Elmadağ Olistostrome consisting of foreland flysch deposits of the Intra-Pontide Ocean: **1 –** Blocks of clastics with phosphate nodules of ?Early Carboniferous age, **2 –** Blocks of sandstones with limestone intercalations of Late Carboniferous age, **3 –** Blocks of Permian detrital and platform limestones, **4 –** Blocks of alternating basic volcanic and platform limestone of Anisian to Ladinian (Middle Triassic) age, **5 –** Pelagic limestone of possible Triassic age, **6 –** Platform limestone of possible Jurassic age, **7 –** Late Cretaceous carbonaceous clastic/clayey carbonate and siliciclastic matrix of the Elmadağ Olistostrome; **c –** Clastics and volcanics of Tertiary age, **d –** Stratigraphic contact; **e –** Main roads; **f –** Drainage system; **g –** Section place (after TEKİN & TUNCER, 2024).

range but are common in Middle–Upper Mississippian successions. Consequently, based on recovered foraminiferal taxa in this sample, the age of sample 21-EL-06 is assigned to the early Serpukhovian (Late Mississippian) (Table 1).

5.3. The Kapaklı Section

The Kapaklı section is entirely composed of shallow-marine, thick-bedded limestones with a rich and diverse foraminiferal assemblage of Serpukhovian age. Recovered foraminiferal taxa from this section allow subdivision of the studied strata into three local foraminiferal biozones corresponding to the lower and upper Serpukhovian (Figs. 12–15; Table 2).

5.3.1. *Neoarchaediscus postrugosus – Biseriella parva Assemblage* Zone

This zone corresponds to the interval between samples 22-KPK-04 and 22-KPK-09 (Fig. 5; Table 2) from the basal part of the Kapaklı section. Rich and diverse foraminiferal taxa were recovered from this interval (Figs. 12, 13) and their distribution is shown in Table 2. The prominent taxa for this zone are *Neoarchaediscus postrugosus* (REITLINGER, 1949), *Biseriella parva* (CHERNYSHEVA, 1948), *Eostaffella* ex gr. *pseudostruvei* (RAUZER-CHERNOUSOVA & BELYAEV in RAUZER-CHERNOUSOVA et al., 1936) and *Janischewskina orbiculata* (GANELINA, 1956). The upper boundary of this zone is marked by the first occurrence datum (FOD) of *Eostaffellina decurta*. Since *Neoarchaediscus postrugosus* was proposed as a zonal marker for the lower Serpukhovian by GIBSHMAN (2001), it has been commonly accepted and utilized as an indicator of the Viséan/Serpukhovian boundary interval by many researchers (e.g., GIBSHMAN, 2003; KULAGINA et al., 2003, 2008, 2011, 2019; CÓZAR et al., 2008a, 2016, 2023; GROVES et al., 2012; KABANOV et al., 2016; NIKOLAEVA et al., 2017; SHENG et al., 2018; CÓZAR & SOMERVILLE, 2021). Based on CÓZAR et al. (2019) a migration of the foraminifers from the Moscow Basin to the Variscan Belt Basin occurred along two migration branches; a northern migration branch (Moscow, Poland/Germany, Belgium/France, England/Ireland, southwestern Spain) and a southern migration branch (Ukraine, southern Alps, Montagne Noire/south-eastern Spain, Cantabrian Mountains and Sahara basins) during the late Viséan–Serpukhovian time interval and this case resulted in diachronism. In addition to different dispersal routes, the authors note that the FOD of the main foraminiferal markers of this interval shows some differences in shallow-water facies of the inner platform and relatively deeper-water settings in the outer platform. Consequently, *Neoarchaediscus postrugosus* is considered an

excellent marker for the base of the Serpukhovian based on its occurrence in both inner and outer platform successions both from the northern and southern migration branches (CÓZAR et al., 2019).

Although *Biseriella parva* displays a similar diachronic FOD as for *Neoarchaediscus postrugosus,* it has been considered a marker taxon for the Viséan–Serpukhovian boundary in many regions (e.g., Morocco by CÓZAR et al., 2011, 2014; Thien-Shan by ORLOV-LABKOVSKY & BENSH, 2015; Pennies by CÓZAR & SOMERVILLE, 2016; Cantabrian by CÓZAR et al., 2016; Iran by ZANDKARIMI et al., 2017, 2019; China by SHENG et al., 2018 and WANG, 2022; South Urals and Belgium by KULAGINA, 2022).

The *Eostaffella* ex gr. *pseudostruvei* traditionally was accepted as an index fossil for the base of the Bashkirian Stage in the Russian zonal schemes (NIKOLAEVA et al., 2020). In addition, it has also been reported from the Viséan–Serpukhovian boundary interval in other studies (e.g., CÓZAR et al., 2008a, 2011, 2014; DEMİREL & ALTINER, 2016; VACHARD et al., 2016).

Bradyina cribrostomata RAUZER-CHERNOUSOVA & REITLINGER (in RAUZER-CHERNOUSOVA & FURSENKO, 1937) is one of the well-known taxa in the upper Serpukhovian successions (e.g., GIBSHMAN & BARANOVA, 2007; CÓZAR et al., 2011; VACHARD et al., 2016; SHENG et al., 2018; KULAGINA et al., 2019; FASSIHI et al., 2022; LIU et al., 2023), but it has also been known from the Lower Serpukhovian strata (e.g., AIZENVERG et al., 1983; CÓZAR & SOMERVILLE, 2021).

In summary, based on the evaluation of all the described foraminiferal taxa in this zone, an early Serpukhovian (Tarusian) age is assigned to the lowermost part of the Kapaklı section comprising the *Neoarchaediscus postrugosus* – *Biseriella parva* Assemblage Zone (Fig. 14). This assemblage zone in this study corresponds to the *Neoarchaediscus postrugosus* Zone of the Russian regional foraminiferal zone for the lowermost Serpukhovian strata (e.g., KULAGINA et al., 2001, 2019; ALEKSEEV et al., 2022) (Fig. 14; Table 2).

5.3.2. *Eostaffellina decurta* Zone

The *Eostaffellina decurta* local zone corresponds to the upper lower part of the Kapaklı section (the interval between samples from 22-KPK-10 to 22-KPK-11; Fig. 5; Table 2). This zone is also represented by a rich and diverse foraminiferal assemblage,

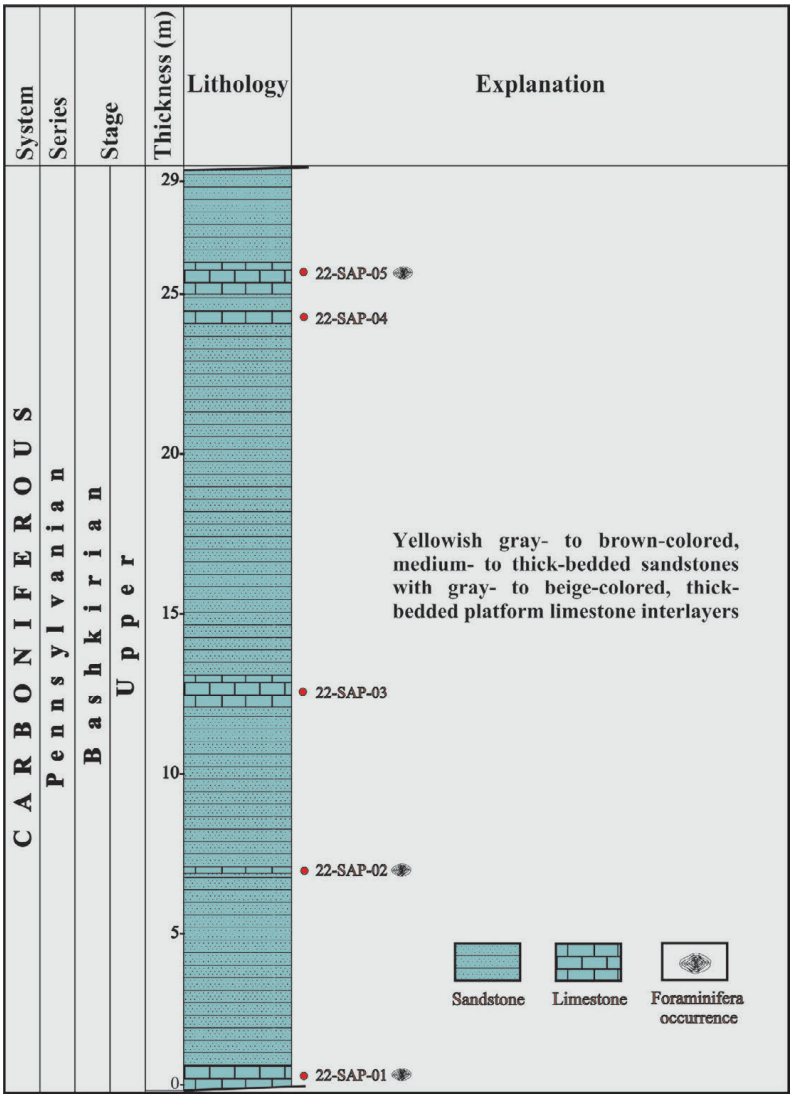

Figure 9. Log of the Sapankıran section and sampling levels.

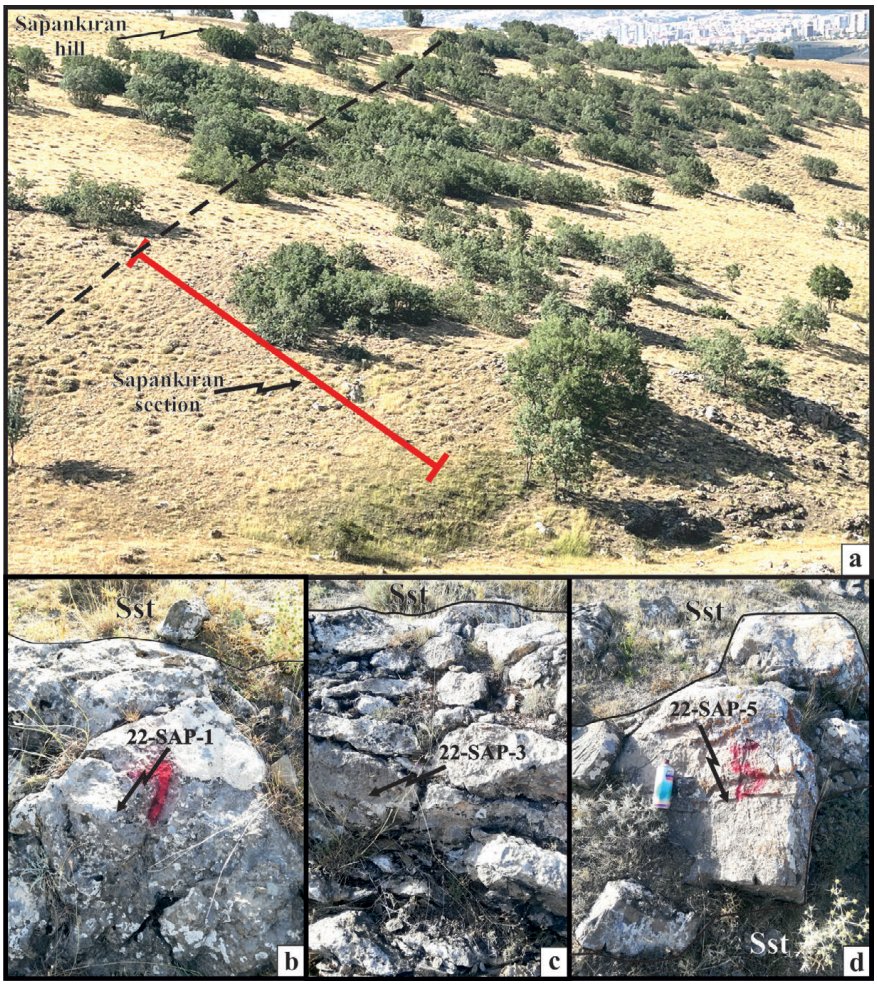

Figure 10. Field photographs from the Sapankıran section in the Yakupabdal region, east of Ankara city: (**a**) General view of the Sapankıran section taken from the sandstone with limestone intercalations exposed to the SE of Sapankıran hill (see Fig. 8 for photograph direction); (**b**) Detail view of the limestone interlayer in the sandstone (Sst) where sample 22-SAP-01 was retrieved from the base of the Sapankıran section; (**c**) Photograph showing one of the major limestone interlayers in the sandstones (Sst) where sample 22-SAP-03 was collected from the central part of this section; (**d**) Photograph showing the location of sample 22-SAP-05 collected from the major limestone interlayer in the sandstone (Sst) at the top of this section.

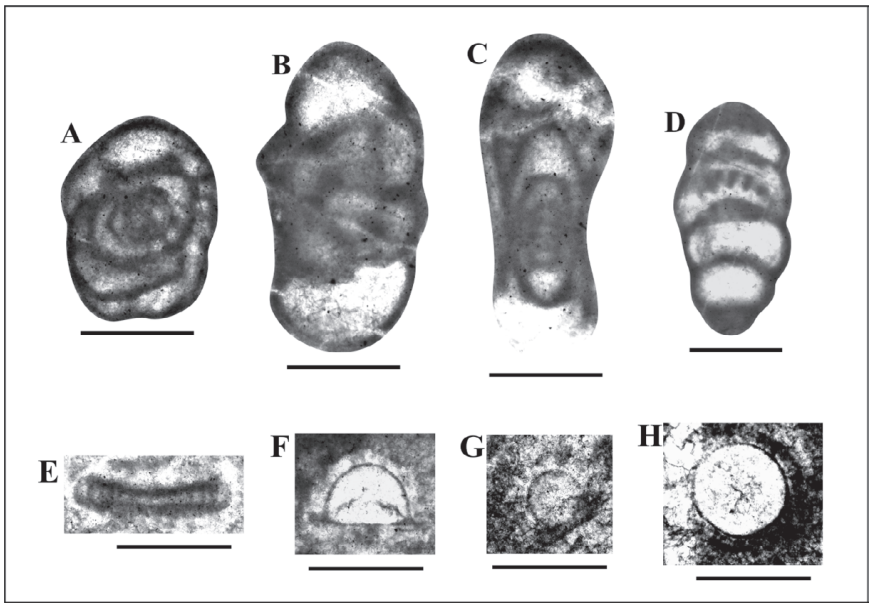

Figure 11. Photomicrographs of the foraminiferal taxa from samples 21-EL-06 of middle Viséan age and 21-EL-41 of early Serpukhovian age. **A –** *Dainella callosa* VDOVENKO in BRAZHNIKOVA & VDOVENKO, 1973, 21-EL-41; **B –** *Pojarkovela*? sp. 1, 21-EL-41; **C –** *Millerella* sp. 1, 21-EL-41; **D –** *Haplophragmella* sp. 1, 21-EL-41; **E –** *Hemidiscopsis muradymica* (KULAGINA in KULAGINA et al., 1992), 21-EL-06; **F –** *Eotuberitina* sp., 21-EL-06; **G–H –** *Radiosphaera* sp., **G** – 21-EL-06, **H –** 21-EL-06. Scale bar for A–C and E–H is 0.25 mm and for D is 0.5 mm.

Table 2. Distribution of the benthic Foraminifera taxa along the Kapaklı section.

EPOCH/STAGE	CARBONIFEROUS										
	Mississippian										
	Serpukhovian										
	Lower								Upper		
Local Zones	*Neoarchaediscus postrugosus*						*Eostaffellina decurta*		*Eostaffellina paraprotvae*		
TAXA/SAMPLES	22-KPK-04	22-KPK-05	22-KPK-06	22-KPK-07	22-KPK-08	22-KPK-09	22-KPK-10	22-KPK-11	22-KPK-12	22-KPK-13	22-KPK-14
***Neoarchaediscus* sp. 1**	X										
Millerella paraumbilicata	X										
Neoarchaediscus parvus	X										
Neoarchaediscus postrugosus	X										
Eostaffella cf. *proikensis*	X										
Eostaffella chusovensis	X										
Endothyra karasikae	X										
Planoendothyra aljutovica	X										
Biseriella parva	X										
Janischewskina orbiculata	X										
***Pseudoglomospira* sp. 1**	X										
***Haplophragmella* sp. 2**	X	?	?	?	X						
Endothyra demini	X	?	?	?	?	X					
Haplophragmella irregularis	X	?	?	?	?	X					
Eostaffella acutiformis	X	?	?	?	X	?	X				
Eostaffella* ex gr. *pseudostruvei	X	X	?	?	?	?	?	X			
***Eolasiodiscus?* sp. 1**		X									
Mediendothyra* aff. *angusta		X									
Eostaffella* ex gr. *postproikensis		X	?	?	?	?	?	X			
Mediocris breviscula celsa			X								
Millerella marblensis			X								
Granuliferella minima			X								
***Hemidiscopsis* sp. 1**			X								
***Koskinobigenerina* sp. 1**			X								
***Koskinobigenerina* sp. 2**			X								
***Bradyina* sp. 1**			X								
***Biseriella* sp. 1**			X	X							
Globivalvulina moderata				X							
***Millerella* sp. 2**				X							
***Planospirodiscus* sp. 1**				X							
***Eostaffella* sp. 1**				X							
***Eolasiodiscus* sp. 2**				X							
***Bradyina* sp. 2**				X	X						
Praeostaffellina macdonaldensis				X	?	?	X				
Mediendothyra posneri					X						
Endothyra kizilica					X						
Mediendothyra cara					X						
Bradyina cribrostomata					X						
***Janischewskina* sp. 1**					X						
***Hemidiscopsis* sp. 2**					X						
Neoarchaediscus gregorii					X	X	X	X			
Eostaffella angusta						X					
Endothyra similis* var. *amplis						X					
Endothyra explicata						X					
Endothyra polita						X					
Neoarchaediscus* ex gr. *borealis						X					
***Koskinobigenerina* sp. 3**						X					
***Brenckleina* sp. 1**						X	X				
***Monotaxinoides* sp. 1**						X	?	X			
Tetrataxis conica							X				
Eostaffellina decurta							X				

EPOCH/STAGE	CARBONIFEROUS										
	Mississippian										
	Serpukhovian										
	Lower								Upper		
Local Zones	*Neoarchaediscus postrugosus*						*Eostaffellina decurta*		*Eostaffellina paraprotvae*		
TAXA/SAMPLES	22-KPK-04	22-KPK-05	22-KPK-06	22-KPK-07	22-KPK-08	22-KPK-09	22-KPK-10	22-KPK-11	22-KPK-12	22-KPK-13	22-KPK-14
***Turrispiroides* sp. 1**							X				
***Eostaffellina* sp. 1**							X				
***Biseriella* sp. 2**							X	?	?	X	
***Janischewskina* sp. 2**								X			
***Monotaxinoides* sp. 2**								X			
Eostaffellina paraprotvae									X		
Endothyranopsis compressa plana									X		
***Brenckleina* sp. 2**									X		
***Neoarchaediscus* sp. 2**									X		
***Endothyra* sp. 1**									X	X	
Neoarchaediscus bykovensis										X	
Endothyra similis											X
Howchinia subplana											X

illustrated in Figure 15, and their distribution is shown in Table 2. While the base of this zone was established by the FOD of the *Eostaffellina decurta* (RAUZER-CHERNOUSOVA, 1948), its upper boundary is marked by the FOD of *Eostaffellina paraprotvae* (RAUZER-CHERNOUSOVA, 1948). *Eostaffellina decurta* is mainly considered a marker for the Steshevian regional substage of the Russian Platform (Fig. 14) and has also been reported in the coeval strata or above from other regions (e.g., GIBSHMAN, 2001, 2003; PAZUKHIN et al., 2010; CÓZAR & SOMERVILLE, 2016; KABANOV et al., 2016; ZANDKARIMI et al., 2017; SHENG et al., 2018). However, its older occurrences are also known from the Cantabrian Mountains, Spain (CÓZAR et al., 2016), France (VACHARD et al., 2016), Pre-Caspian Basin (BRENCKLE & COLLINS, 2017), and South Urals (KULAGINA, 2022). Another important taxon *Brenckleina* in this zone was reported from the uppermost Lower Serpukhovian successions (CÓZAR & SOMERVILLE, 2014; CÓZAR et al., 2016), but is more commonly known from the upper Serpukhovian strata (CÓZAR et al., 2008b, 2014).

Based on the above arguments, a late early Serpukhovian (Steshevian) age is assigned to the upper part of the Kapaklı section corresponding to the local zone "*Eostaffellina decurta"* (Fig. 14; Table 2).

5.3.3. *Eostaffellina paraprotvae* Zone

The *Eostaffellina paraprotvae* local zone corresponds to the upper part of the Kapaklı section (interval between samples from 22-KPK-12 to 22-KPK-14; Fig. 5; Table 2). This zone is represented by relatively poor foraminiferal taxa in contrast to the other two zones, illustrated in Figure 15, and their distribution is shown in Table 2. While the base of this zone was established by the FOD of the *Eostaffellina paraprotvae* (RAUZER-CHERNOUSOVA, 1948), its upper boundary could not be defined as it was disturbed by a fault. *Eostaffellina paraprotvae* was defined for the first time in the Serpukhovian (Protvian substage) from the Moscow Basin by RAUZER-CHERNOUSOVA (1948). While *Eostaffellina paraprotvae* was also described in the uppermost lower Serpukhovian strata in some studies (e.g., GIBSHMAN, 2003; KULAGINA et al., 2009; SHENG et al., 2018), it is commonly assigned as a reliable diagnostic foraminifer for the Protvian substage in recent studies (e.g., CÓZAR et al., 2011; KULAGINA et al., 2019; FASSIHI et al., 2022). Based on the presence of *Eostaffellina paraprotvae* at the base of this zone, a late Serpukhovian (Protvian–Zapaltyubian?) age is assigned to the upper part of the Kapaklı section (Fig. 14; Table 2).

5.4. The Sapankıran Section

A total of five samples (22-SAP-01 to 22-SAP-05) were collected from the carbonate interlayers in sandstones for determining foraminiferal assemblages from this section. While three of the samples (22-SAP-01, 22-SAP-02, and 22-SAP-05) are positive for foraminiferal fauna, two of the samples (22-SAP-03 and 22-SAP-04) are barren (Fig. 9).

The first sample (22-SAP-01) from the base of the Sapankıran section consists of *Staffellaeformes bona* (GROZDILOVA & LEBEDEVA, 1954), *Semistaffella*? cf. *minuscilaria* (REITLINGER in KULAGINA, 1988), *Eostaffella* sp. A and *Schubertella* sp. (Fig. 16; Table 3). *Semistaffella*? cf. *minuscilaria* was described for the first time from the upper Serpukhovian strata of the southern Urals (Russia) by KULAGINA (1988). However, its occurrence has also been reported from the lower Bashkirian (Syuranian substage) strata (e.g., southern Urals by KULAGINA et al., 1992, 2000, 2014; Türkiye from AKBAŞ & OKUYUCU, 2021). *Staffellaeformes bona*, which was described for the first time from the base of the Moscovian (Vereian substage) strata in the Kolva–Vishhera region, is a useful biostratigraphic marker for the Askynbashian and Arkhangelskian substages (Fig. 14) of the Bashkirian stage (e.g., BENSH, 1969;

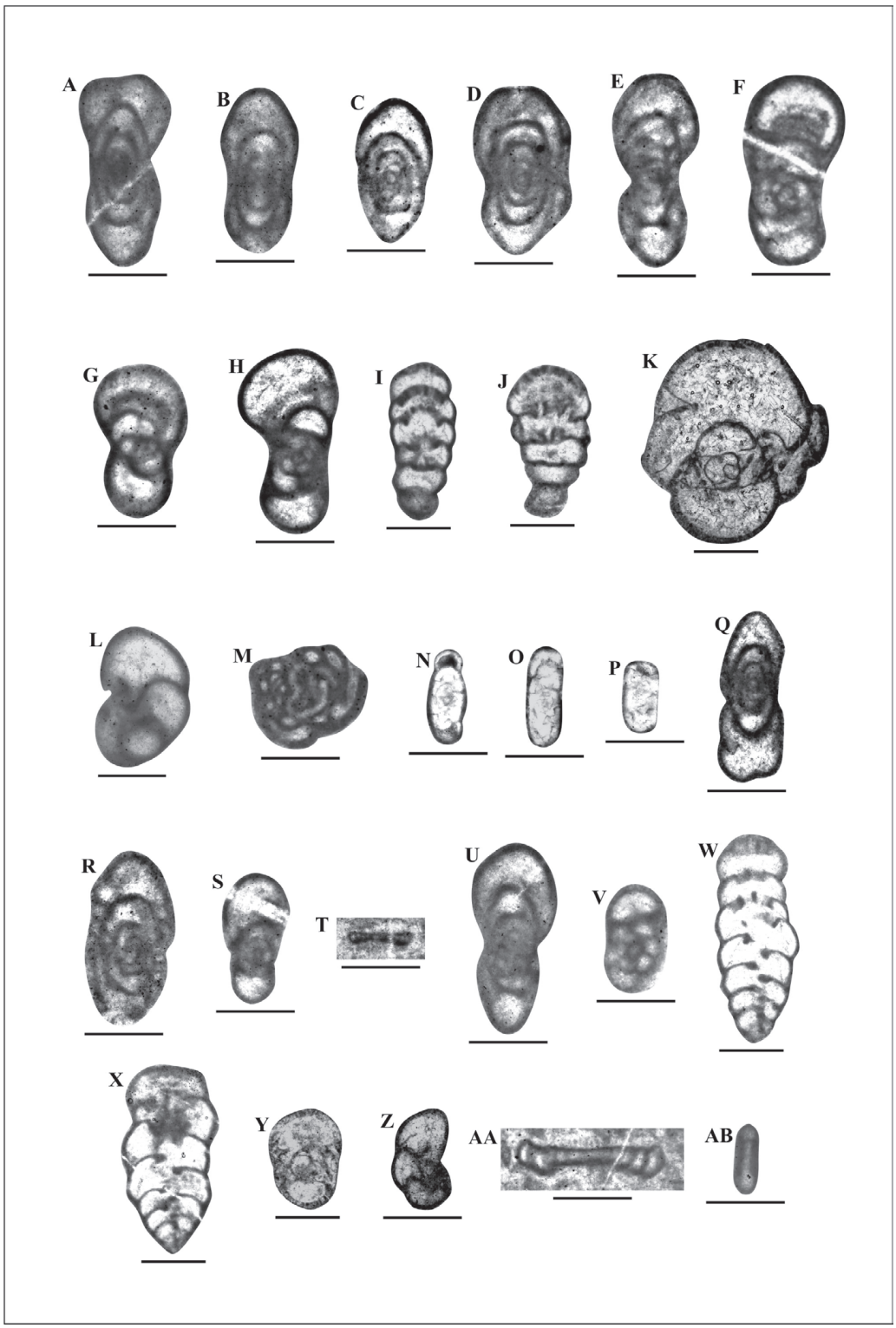

Figure 12. Photomicrographs of the foraminiferal taxa from the *Neoarchaediscus postrugosus-Biseriella parva* Assemblage Zone in the Kapaklı section of early Serpukhovian age; **A –** *Eostaffella* ex gr. *pseudostruvei* (RAUZER-CHERNOUSOVA & BELYAEV, in RAUZER-CHERNOUSOVA et al., 1936), 22-KPK-04; **B –** *Eostaffella acutiformis* KIREEVA in RAUZER-CHERNOUSOVA et al., 1951, 22-KPK-04; **C –** *Eostaffella* cf. *proikensis* RAUZER-CHERNOUSOVA, 1948, 22-KPK-04; **D –** *Eostaffella chusovensis acutiformis* KIREEVA in RAUZER-CHERNOUSOVA et al., 1951, 22-KPK-04; **E –** *Millerella paraumbilicata* MANUKALOVA-GREBENYUK, ILYINA & SEREZHNIKOVA in MANUKALOVA-GREBENYUK et al., 1969, 22-KPK-04; **F –** *Endothyra demini* DURKINA, 1959, 22-KPK-04; **G –** *Endothyra karasikae* DURKINA, 1959, 22-KPK-04; **H –** *Planoendothyra aljutovica* (REITLINGER, 1950), 22-KPK-04; **I –** *Haplophragmella irregularis* RAUZER-CHERNOUSOVA, 1938, 22-KPK-04; **J –** *Haplophragmella* sp. 2, 22-KPK-04; **K –** *Janischewskina orbiculata* (GANELINA, 1956), 22-KPK-04; **L –** *Biseriella parva* (CHERNYSHEVA, 1948), 22-KPK-04; **M –** *Pseudoglomospira* sp. 1, 22-KPK-04; **N –** *Neoarchaediscus postrugosus* (REITLINGER, 1949), 22-KPK-04; **O –** *Neoarchaediscus parvus* (RAUZER-CHERNOUSOVA, 1948), 22-KPK-04; **P –** *Neoarchaediscus* sp. 1, 22-KPK-04; **Q –** *Eostaffella* ex gr. *pseudostruvei* (RAUZER-CHERNOUSOVA & BELYAEV in RAUZER-CHERNOUSOVA et al., 1936), 22-KPK-05; **R –** *Eostaffella* ex gr. *postproikensis* VDOVENKO in BRAZHNIKOVA et al., 1967, 22-KPK-05; **S –** *Mediendothyra* aff. *angusta* (DURKINA, 1959), 22-KPK-05; **T –** *Eolasiodiscus*? sp. 1, 22-KPK-05; **U –** *Millerella marblensis* THOMPSON, 1942, 22-KPK-06; **V –** *Granuliferella minima* (LIPINA, 1955), 22-KPK-06; **W –** *Koskinobigenerina* sp. 1, 22-KPK-06; **X –** *Koskinobigenerina* sp. 2, 22-KPK-06; **Y –** *Bradyina* sp. 1, 22-KPK-06; **Z –** *Biseriella* sp. 1, 22-KPK-06; **AA –** *Hemidiscopsis* sp. 1, 22-KPK-06; **AB –** *Mediocris breviscula* subsp. *celsa* POYARKOV, 1965, 22-KPK-06. Scale bar for A–C, E–L, Q–Z is 0.25 mm and for D, M–P, AA–AB is 0.5 mm.

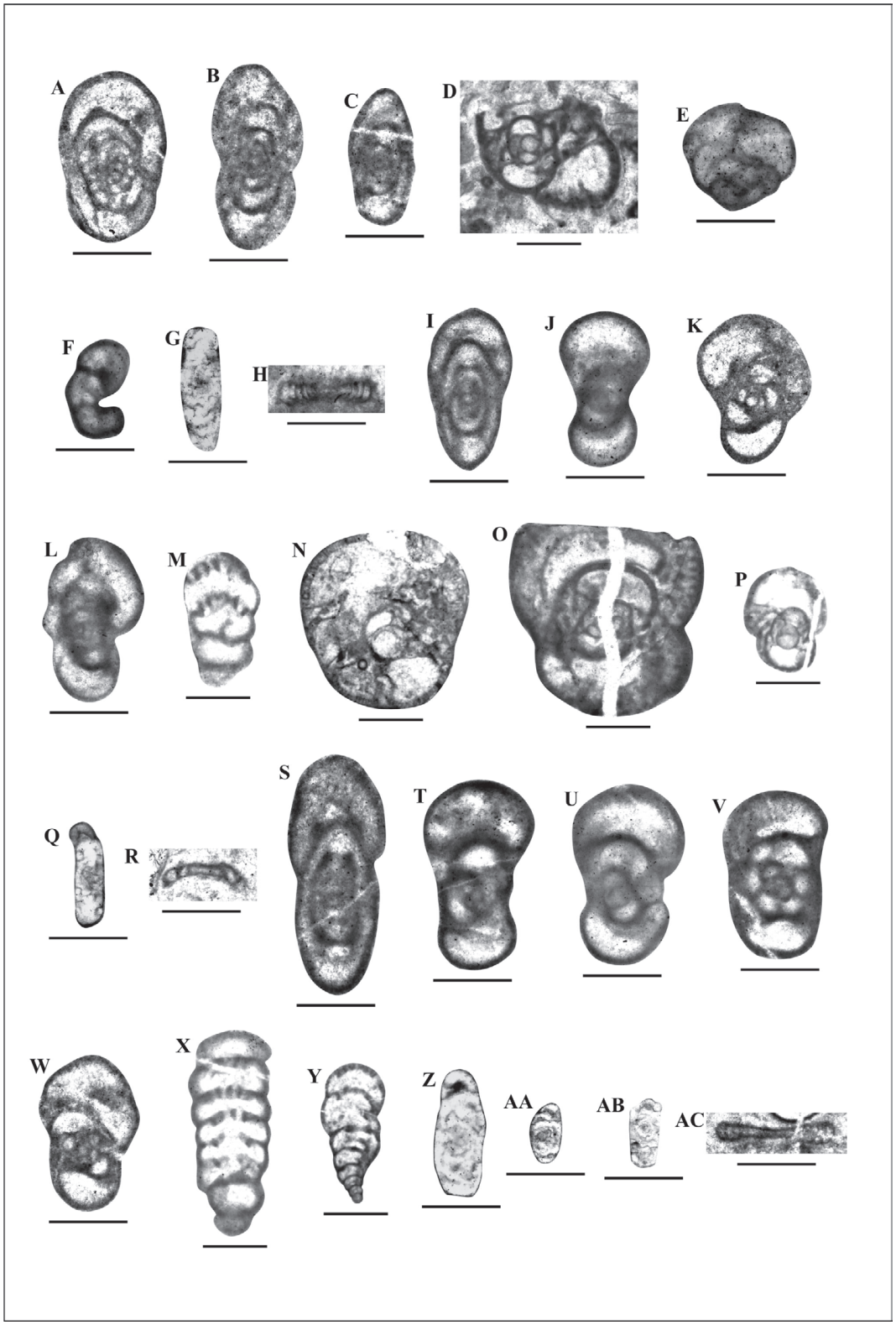

Figure 13. Photomicrographs of the foraminiferal taxa from the *Neoarchaediscus postrugosus- Biseriella parva* Assemblage Zone in the Kapaklı section of early Serpukhovian age (Continued). **A –** *Praeostaffellina macdonaldensis* CÓZAR et al., 2008b, 22-KPK-07; **B –** *Millerella* sp. 2, 22-KPK-07; **C –** *Eostaffella* sp. 1, 22-KPK-07; **D –** *Bradyina* sp. 2, 22-KPK-07; **E –** *Globivalvulina moderata* REITLINGER, 1949, 22-KPK-07; **F –** *Biseriella* sp. 1, 22-KPK-07; **G –** *Planospirodiscus* sp. 1, 22-KPK-07; **H –** *Eolasiodiscus* sp. 2, 22-KPK-07; **I –** *Eostaffella acutiformis* KIREEVA in RAUZER-CHERNOUSOVA et al., 1951, 22-KPK-08; **J –** *Mediendothyra posneri* (GANELINA, 1956), 22-KPK-08; **K –** *Mediendothyra cara* (SHLYKOVA in DURKINA, 1959), 22-KPK-08; **L –** *Endothyra kizilica* MALAKHOVA, 1980, 22-KPK-08; **M –** *Haplophragmella* sp. 2, 22-KPK-08; **N –** *Bradyina cribrostomata* RAUZER-CHERNOUSOVA & REITLINGER in RAUZER-CHERNOUSOVA & FURSENKO, 1937, 22-KPK-08; **O –** *Bradyina* sp. 2, 22-KPK-08; **P –** *Janischewskina* sp. 1, 22-KPK-08; **Q –** *Neoarchaediscus gregorii* (DAIN in DAIN & GROZDILOVA, 1953), 22-KPK-08; **R –** *Hemidiscopsis* sp. 2, 22-KPK-08; **S –** *Eostaffella angusta* KIREEVA in RAUZER-CHERNOUSOVA et al., 1951, 22-KPK-09; **T –** *Endothyra demini* DURKINA, 1959, 22-KPK-09; **U –** *Endothyra similis* var. *amplis* SHLYKOVA, 1951, 22-KPK-09; **V –** *Endothyra explicata* GANELINA, 1956, 22-KPK-09; **W –** *Endothyra polita* DURKINA, 1959, 22-KPK-09; **X –** *Haplophragmella irregularis* RAUZER-CHERNOUSOVA, 1938, 22-KPK-09; **Y –** *Koskinobigenerina* sp. 3, 22-KPK-09; **Z –** *Neoarchaediscus* ex gr. *borealis* (REITLINGER, 1949), 22-KPK-09; **AA –** *Brenckleina* sp. 1, 22-KPK-09; **AB –** *Asteroarchaediscus* sp. 1, 22-KPK-09; **AC –** *Monotaxinoides* sp. 1, 22-KPK-09. Scale bar for A–C, E–L, Q–W, Z–AC is 0.25 mm and for D, M–P, X–Y is 0.5 mm.

ICS Global Scale			Regional scale foraminiferal zonations from Russia (ALEKSSEEV et al., 2022) (KULAGINA et al., 2001, 2019)		Foraminiferal zonations from Türkiye (central Taurides-Hadim Nappe) (ALTINER & ÖZGÜL, 2001)	Foraminiferal zonations from Türkiye (central Taurides-Hadim Nappe) (AKBAŞ & OKUYUCU, 2022)	This study foraminiferal assamblage / zonations	
CARBONIFEROUS	Lower Pennsylvanian	Bashkirian	Upper	Arkhangelskian	*Aljutovella tikhonovichi* *Verella spicata*	*Profusulinella*	*Tikhonovichiella tikhonovichi* *Verella spicata*	
					Ozawainella pararhomboidalis *Pseudostaffella gorskyi*			For. assambalage in the Sapankıran s.: *Staffellaeformes bona*, *Semistaffella*? cf. *minuscularia*, *Eostaffella* sp. A, *Schubertella* sp., *Staffellaeformes parva*, *Staffellaeformes* cf. *staffellaeformis*, *Eostaffella* sp. B, *Endothyra* sp., *Millerella*? sp.
			Lower	Askynbashian	*Pseudostaffella praegorskyi* *Staffellaeformes staffellaeformis*	*Pseudostaffella antiqua grandis*	*Staffellaeformes staffellaeformis* *Staffellaeformes parva parva*	
				Akavasian	*Pseudostaffella antiqua*	*Pseudostaffella antiqua*	*Pseudostaffella antiqua* *Pseudostaffella sofronizkyi*	
				Syuranian	*Semistaffella variabilis* *Semistaffella minuscularia*	*Semistaffella* *Plectostaffella jakhensis*	*Plectostaffella bogdanovkensis* *Plectostaffella varvariensis*	
					Plectostaffella bogdanovkensis			
	Upper Mississippian	Serpukhovian		Zapaltyubian	*Monotaxinoides transitorius*	*Eostaffella postmosquensis* *Plectostaffella* ex gr. *bogdanovkensis*		Foraminiferal zonations in the Kapaklı section: ?
				Protvian	*Eostaffellina paraprotvae*	*Eostaffellina paraprotvae* *Bradyina cribrostomata*		*Eostaffellina paraprotvae*
				Steshevian	*Neoarchaediscus postrugosus*	*Pseudoendothyra* ex gr. *illustria* *Eostaffella pseudostruvei*		*Eostaffellina decurta*
				Tarusian				*Neoarchaediscus postrugosus* *Biseriella parva*

Figure 14. Correlation of the Serpukhovian and Bashkirian Russian Regional Stages and their foraminiferal zones to the Tauride–Anatolide Platform and blocks in the Upper Cretaceous Elmadağ Olistostrome in this study.

KULAGINA et al., 2001; ORLOV-LABKOVSKY & BENSH, 2015; AKBAŞ & OKUYUCU, 2021).

Sample 22-SAP-02 from the overlying carbonate interlayer in the Sapankıran section contains *Staffellaeformes parva* (LEE & CHEN in LEE et al., 1930) and *Staffellaeformes* cf. *staffellaeformis* (KIREEVA in RAUZER-CHERNOUSOVA et al., 1951) (Fig. 16; Table 3). The characteristic late Bashkirian taxon *Staffellaeformes parva* was first described by LEE et al. (1930) in South China. Later, *Staffellaeformes parva* has been reported mainly from the upper Lower–upper Bashkirian (Askynbashian–Arkhangelskian) deposits of the southern Urals (Russia) by KULAGINA et al. (2001), KULAGINA (2008, 2009), Alburz Mountains (Iran) by LEVEN & GORGIJ (2011), Darvaz (Turkmenistan) and Pamir Mountains (Tajikistan) by LEVEN (2012) and the Hadim Nappe (Türkiye) by AKBAŞ & OKUYUCU (2021). In addition, *Staffellaeformes parva* has also been determined as a long-ranging taxon (late Bashkirian to early Moscovian) in the Russian Platform by RAUZER-CHERNOUSOVA et al. (1951), Kolva–Vishera (Russia) by GROZDILOVA & LEBEDEVA (1954), Alai (Turkmenistan) by DZHENCHURAEVA (1979), Cantabria Mountains (Spain) by GINKEL (1987) and VILLA (1995) and Anatolian Platform (Türkiye) by DZHENCHURAEVA & OKUYUCU (2007).

The other significant foraminiferal taxon from sample 22-SAP-02 is *Staffellaeformes* cf. *staffellaeformis,* which was first described by KIREEVA (in RAUZER-CHERNOUSOVA et al., 1951) from the lower Moscovian strata in the Russian Platform. *Staffellaeformes staffellaeformis* has been determined from the upper Bashkirian–lower Moscovian successions in subsequent studies from the Alai (Turkmenistan) by DZHENCHURAEVA (1979) and Cantabrian Mountains (Spain) by VILLA (1995). It has mainly been determined from the upper Lower–upper Bashkirian (Askynbashian–Arkhangelskian) strata (Fig. 14) and used as a marker for this stratigraphic interval (e.g., KULAGINA et al., 2001, 2003; DZHENCHURAEVA & OKUYUCU, 2007; KULAGINA, 2008, 2009; LEVEN & GORGIJ, 2011; LEVEN, 2012; AKBAŞ & OKUYUCU, 2021, 2022).

Sample 22-SAP-05 from the upper part of the Sapankıran section produced a poor foraminiferal assemblage consisting only of *Eostaffella* sp. B, *Endothyra* sp. and *Millerella*? sp. (Fig. 16; Table 3). Despite their long stratigraphic ranges, these described genera are well-known components of the Bashkirian successions (e.g., KULAGINA et al., 1992, 2001; AKBAŞ & OKUYUCU, 2021).

Based on the evaluation of the obtained foraminiferal assemblage, the age of the Sapankıran section is upper Lower–upper Bashkirian (Askynbashian–Arkhangelskian), mainly based on the taxa from 22-SAP-02 (Fig. 14; Table 3).

6. STRATIGRAPHIC AND BIOSTRATIGRAPHIC CORRELATIONS

The stratigraphic and biostratigraphic features of the studied sections (Kapaklı and Sapankıran) and isolated samples (21-EL-06 and 21-EL-41) in this study have some similarities and differences with coeval rock units in the Tauride–Anatolide Platform (e.g., the Hadim, Bolkar Dağı, and Beyşehir–Hoyran nappes originated from the IAE Ocean) and previously described Intra-Pontide remnants (Elmadağ Olistostrome)

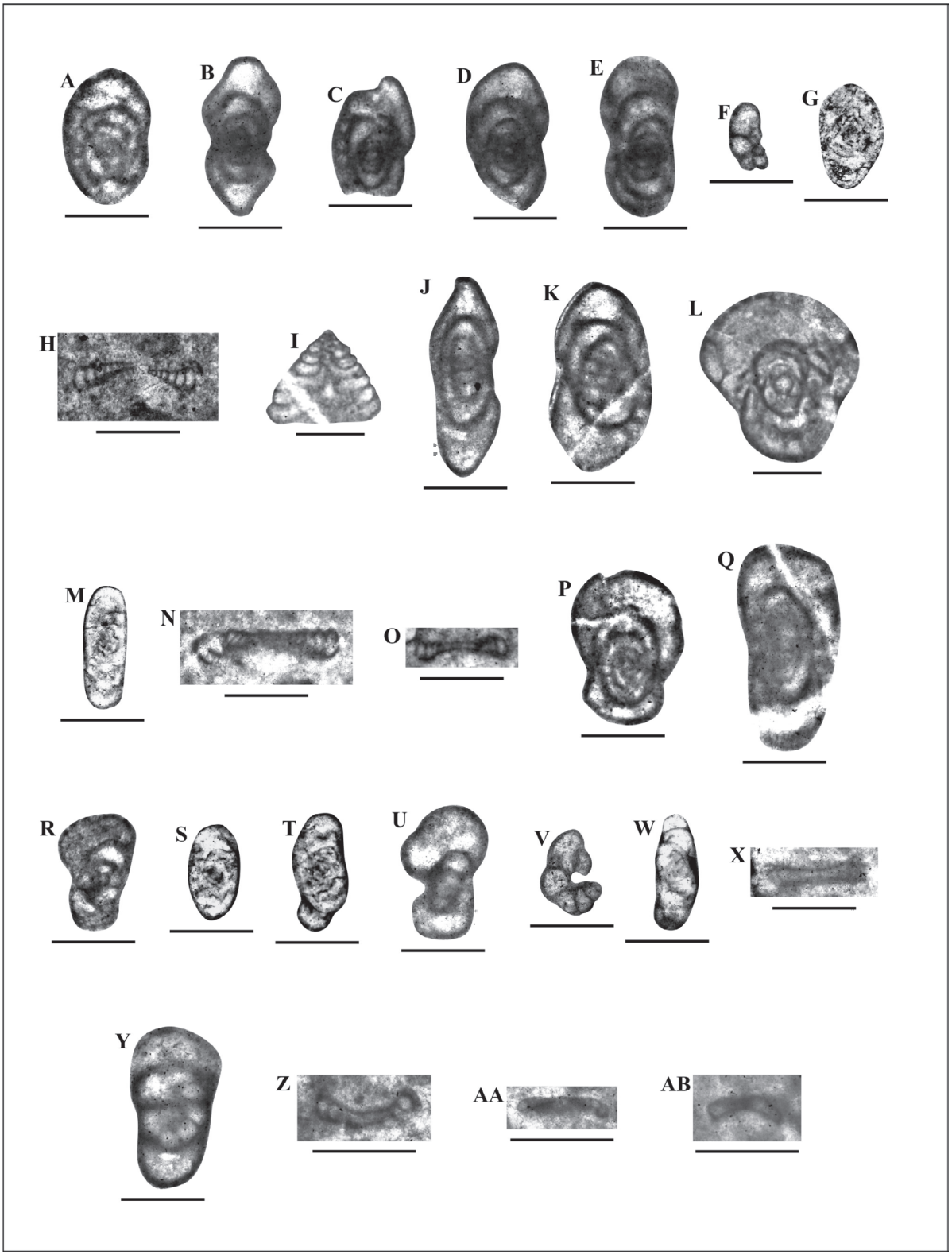

Figure 15. Photomicrographs of the foraminiferal taxa from the *Eostaffellina decurta* Zone and *Eostaffellina paraprotvae* Zone in the Kapaklı section of early late-late Serpukhovian age. **A –** *Praeostaffellina macdonaldensis* CÓZAR et al., 2008b, 22-KPK-10; **B –** *Eostaffella acutiformis* KIREEVA in RAUZER-CHERNOUSOVA et al., 1951, 22-KPK-10; **C–D –** *Eostaffellina decurta* (RAUZER-CHERNOUSOVA, 1948), both from 22-KPK-10; **E –** *Eostaffellina* sp. 1, 22-KPK-10; **F –** *Biseriella* sp. 2, 22-KPK-10; **G –** *Brenckleina* sp. 1, 22-KPK-10; **H –** *Turrispiroides* sp. 1, 22-KPK-10; **I –** *Tetrataxis conica* EHRENBERG, 1854, 22-KPK-10; **J –** *Eostaffella* ex gr. *pseudostruvei* (RAUZER-CHERNOUSOVA & BELYAEV in RAUZER-CHERNOUSOVA et al., 1936), 22-KPK-11; **K –** *Eostaffella* ex gr. *postproikensis* VDOVENKO in BRAZHNIKOVA et al., 1967, 22-KPK-11; **L –** *Janischewskina* sp. 2, 22-KPK-11; **M –** *Neoarchaediscus gregorii* (DAIN in DAIN & GROZDILOVA, 1953), 22-KPK-11; **N –** *Monotaxinoides* sp. 1, 22-KPK-11; **O –** *Monotaxinoides* sp. 2, 22-KPK-11; **P –** *Eostaffellina paraprotvae* (RAUZER-CHERNOUSOVA, 1948), 22-KPK-12; **Q –** *Endothyranopsis compressa* subsp. *plana* BRAZHNIKOVA in BRAZHNIKOVA et al., 1967, 22-KPK-12; **R –** *Endothyra* sp. 1, 22-KPK-12; **S –** *Brenckleina* sp. 2, 22-KPK-12; **T –** *Neoarchaediscus* sp. 2, 22-KPK-12; **U –** *Endothyra* sp. 1, 22-KPK-13; **V –** *Biseriella* sp. 2, 22-KPK-13; **W –** *Neoarchaediscus bykovensis* SOSIPATROVA, 1966, 22-KPK-13; **X –** *Monotaxinoides* sp. 2, 22-KPK-13; **Y –** *Endothyra similis* RAUZER-CHERNOUSOVA & REITLINGER in RAUZER-CHERNOUSOVA et al., 1936, 22-KPK-14; **Z–AB –** *Howchinia subplana* (BRAZHNIKOVA & YARTSEVA, 1956), all from 22-KPK-14. Scale bar for A–H, J–K, M–AB is 0.25 mm and for I and L is 0.5 mm.

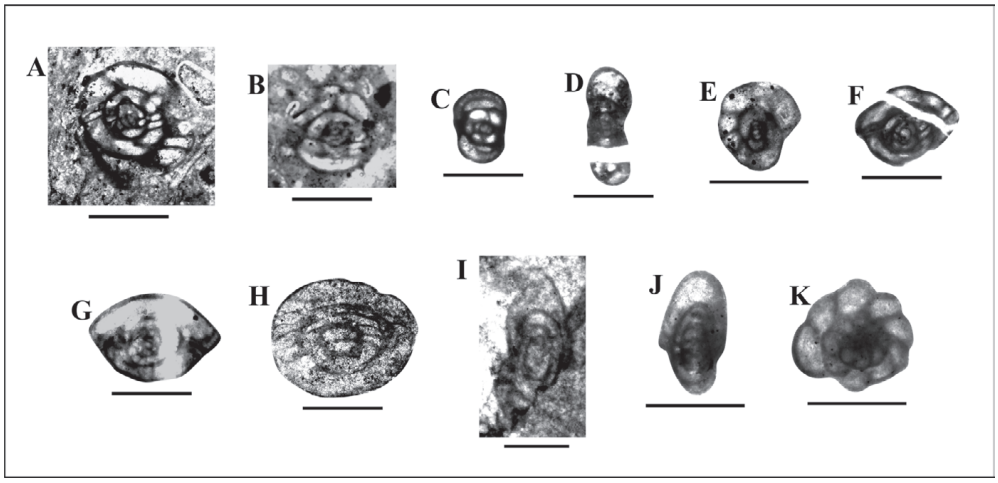

Figure 16. Photomicrographs of the foraminiferal taxa from the Sapankıran section. **A–B –** *Staffellaeformes bona* (GROZDILOVA & LEBEDEVA, 1954), both from 22-SAP-01; **C –** *Semistaffella* cf. *minuscilaria* (REITLINGER in KULAGINA, 1988), 22-SAP-01; **D –** *Eostaffella* sp. A, 22-SAP-01; **E –** *Schubertella* sp., 22-SAP-01; **F–G –** *Staffellaeformes parva* (LEE & CHEN in LEE et al., 1930), both from 22-SAP-02; **H –** *Staffellaeformes* cf. *staffellaeformis* (KIREEVA in RAUZER-CHERNOUSOVA et al., 1951), 22-SAP-02; **I –** *Millerella*? sp., 22-SAP-05; **J –** *Eostaffella* sp. B, 22-SAP-05; **K –** *Endothyra* sp., 22-SAP-05. Scale bar for A–D, F–H is 0.5 mm and for E, I–K is 0.25 mm.

overlying the Sakarya Composite Terrane (e.g., ÖZGÜL, 1997; ALTINER & ÖZGÜL, 2001; OKUYUCU et al., 2018, 2024; AKBAŞ & OKUYUCU, 2021).

6.1. Correlation to the Tauride–Anatolide Platform

6.1.1. The Hadim Nappe

The Hadim Nappe has continuous successions comprising Middle?–Upper Devonian – Upper Cretaceous shallow marine platform limestones and siliciclastic rock units (BLUMENTHAL, 1944; BRUNN et al., 1970, 1971; ÖZGÜL, 1976, 1984, 1997; see OKUYUCU et al., 2018 for brief review). Within this continuous succession, Viséan–Bashkirian rock units are represented by limestone with shale interbeds of Viséan age, quartz arenite sandstone with rare carbonate intercalations of the Serpukhovian age, and limestones rich in foraminifera and calcareous algae with some siliciclastic interlayers of the Bashkirian age (e.g., ÖZGÜL, 1997; ATAKUL-ÖZDEMİR et al., 2011; DEMİREL & ALTINER, 2016; AKBAŞ & OKUYUCU, 2021; AKBAŞ, 2024) (Fig. 17).

The lithostratigraphic and biostratigraphic characteristics of the isolated sample 21-EL-41 of middle Viséan age have a close resemblance to the Viséan rock units of the Hadim Nappe. Lithologically, sample 21-EL-41 represents grey-coloured and thick-bedded shallow marine platform limestone and is similar to the dominant lithological characteristics of the Viséan limestones from the Hadim Nappe (GÜVENÇ, 1965, 1977; ÖZGÜL, 1997; AKBAŞ, 2024) (Fig. 17). The obtained foraminiferal fauna from this platform limestone sample (21-EL-41) also exhibits a good correlation to the middle Viséan foraminiferal fauna of the Hadim Nappe with the occurrence of similar characteristic taxa (e.g., *Dainella callosa* and *Pojarkovella* spp. by AKBAŞ, 2024).

Whereas the Serpukhovian succession of the Hadim Nappe is mainly represented by quartz arenitic sandstones with rare limestone intercalations (ÖZGÜL, 1997), the coeval succession of the Kapaklı section is entirely characterized by thick-bedded platform limestones. The Serpukhovian foraminiferal biozonation of the Hadim Nappe has not been documented due to the scarcity of the limestone strata. Additionally, ATAKUL-ÖZDEMİR et al. (2011) and DEMİREL & ALTINER (2016) have provided only limited data from the Serpukhovian–Bashkirian and Viséan–Serpukhovian boundary intervals, respectively. (Fig. 17). ALTINER & ÖZGÜL (2001) reported three foraminiferal biozones along the Serpukhovian strata of the Hadim Nappe (ST1: *Pseudoendothyra* ex gr. *illustria-Eostaffella pseudostruvei* Zone, ST2: *Eostaffella paraprotvae–Bradyina cribrostomata* Zone and ST3: *Eostaffella postmosquensis-Plectostaffella* ex gr. *bogdanovkensis* Zone) without any illustration (Fig. 14). The lowermost foraminiferal Zone of ALTINER & ÖZGÜL (2001) (ST1) mainly includes long-ranging foraminiferal taxa (e.g., *Eostaffella pseudostruvei*), and their first occurrence datum is at the Viséan (e.g., *Endothyranopsis crassa* (BRADY, 1870), *Biseriella parva*, *Omphalotis minima* (RAUZER-CHERNOUSOVA & REITLINGER in RAUZER-CHERNOUSOVA et al., 1936), *Mediocris mediocris* (VISSARIONOVA, 1948)). In addition to this, most of the

Table 3. Distribution of the benthic Foraminifera taxa along the Sapankıran section.

EPOCH/STAGE	CARBONIFEROUS		
	Pennsylvanian		
	Bashkirian		
	upper Lower-Upper		
TAXA/SAMPLES	22-SAP-01	22-SAP-02	22-SAP-05
Staffellaeformes bona	X		
Semistaffella*? cf. *minuscilaria	X		
***Eostaffella* sp. A**	X		
***Schubertella* sp.**	X		
Staffellaeformes parva		X	
Staffellaeformes* cf. *staffellaeformis		X	
***Eostaffella* sp. B**			X
***Endothyra* sp.**			X
***Millerella*? sp.**			X

foraminiferal taxa belonging to the ST1 Zone were also reported for the uppermost Viséan foraminiferal Zone (VT5) by ALTINER & ÖZGÜL (2001). According to the absence of the index foraminiferal taxa for the base of the Serpukhovian and quite similar faunal content between VT5 and ST1, it can be argued that the foraminiferal assemblage of the ST1 Zone was represented by a Viséan–Serpukhovian mixed fauna. Moreover, even though the ST2 Zone includes Serpukhovian foraminiferal taxa, the ST1/ST2 boundary could be considered doubtful based on insufficient index foraminiferal data and the position of this boundary in between the sandstone layers. ALTINER & ÖZGÜL's (2001) upper Serpukhovian ST3 Zone consists of a Serpukhovian–Bashkirian mixed fauna, as in their ST1 Zone, and includes index taxa for the base of the Bashkirian as *Plectostaffella varvariensis* (BRAZHNIKOVA & POTIEVSKAYA, 1948) and *P. bogdanovkensis* REITLINGER, 1980 (Fig. 14). However, the limestone succession of the Kapaklı section with numerous index foraminiferal taxa of Serpukhovian age, (e.g., *N. postrugosus* and *Biseriella parva* for the lower part, *Eostaffellina decurta* for the upper lower part and *Eostaffellina paraprotvae* for the upper part), allows us to further subdivide the Serpukhovian stage into three local foraminiferal biozones (e.g., *Neoarchaediscus postrugosus-Biseriella parva* Assemblage Zone, *Eostaffellina decurta* Zone and *Eostaffellina paraprotvae* Zone) comparable with the Russian Platform (Fig. 14) and western Europe.

The other Serpukhovian fauna obtained from the isolated sample 21-EL-06 in this study includes *Hemidiscopsis muradymica*, which has been considered as a potential marker for the Viséan-Serpukhovian boundary in many previous studies (e.g., KULAGINA et al., 1992; NIKOLAEVA et al., 2009, 2020; PAZUKHIN et al., 2010; CÓZAR et al., 2015; VACHARD et al., 2016). The comparable coeval strata of the Hadim Nappe with sample 21-EL-06 were studied by

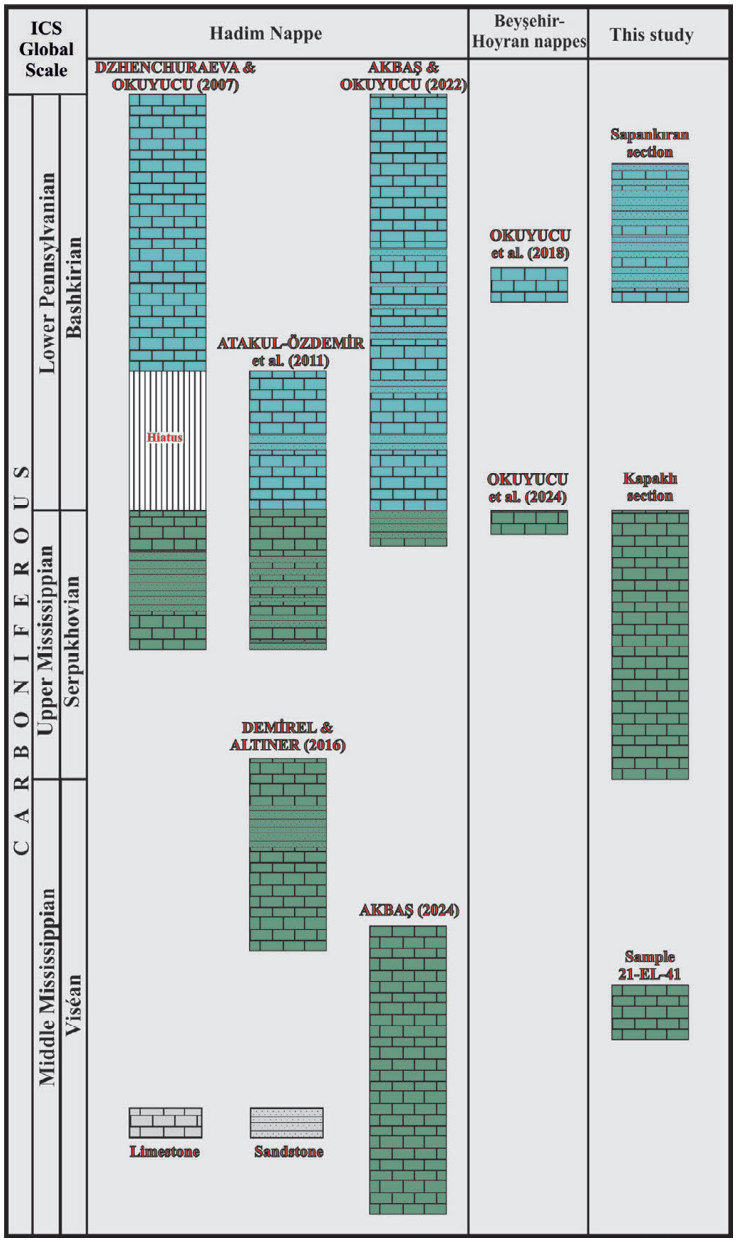

Figure 17. Lithostratigraphic correlation of the Carboniferous rock units of the Tauride–Anatolide Platform to the Carboniferous blocks in the Upper Cretaceous Elmadağ Olistostrome in the present study.

DEMİREL & ALTINER (2016). *Hemidiscopsis muradymica* recovered from this sample is more useful for the description of the lowermost boundary of the Serpukhovian stage against *Eostaffella pseudostruvei* proposed by ALTINER & ÖZGÜL (2001) and DEMİREL & ALTINER (2016) for the base of Serpukhovian stage in the Hadim Nappe sequence. In contrast, DEMİREL & ALTINER (2016) reported a quite different lithology for the lower Serpukhovian/uppermost Viséan strata, incompatible with the general characterization of the deposits for this interval of the Hadim Nappe. While the uppermost Viséan–lower Serpukhovian strata in the Hadim Nappe mainly consist of limestone and sandstone alternations, this interval is completely represented by carbonates in the Aygörmez section by DEMİREL & ALTINER's (2016) from the eastern Taurides, contrary to what is widely known.

The upper Lower–upper Bashkirian (Askynbashian–Arkhangelskian) succession of the Sapankıran section exhibits close similarity with the coeval strata of the Hadim Nappe (ÖZGÜL, 1997; AKBAŞ & OKUYUCU, 2021). Lithologically, both are characterized by an alternation of limestones and sandstones with similar and important foraminiferal taxa (e.g., *Staffellaeformes parva* and *Staffellaeformes staffellaeformis*) for this time interval (ALTINER & ÖZGÜL, 2001; AKBAŞ & OKUYUCU, 2021) (Fig. 17). Bashkirian rock units of the Hadim Nappe in the eastern Taurides (Siyah Aladağ Nappe) given by DZHENCHURAEVA & OKUYUCU (2007) are mainly composed of carbonate-dominated lithologies. Although there are some lithological differences, the foraminiferal assemblages (e.g., *Semistaffella minuscularia* and *Staffellaeformes staffellaeformis*) recovered from the eastern Taurides are similar to those obtained from the Intra-Pontide units (this study) and the central Taurides (AKBAŞ & OKUYUCU, 2021) (Fig. 17).

6.1.2. The Bolkar Dağı Nappe

The Bolkar Dağı Nappe consists of variably metamorphosed clastic and carbonate rock units of Middle Devonian to Late Cretaceous age, with a hiatus corresponding to the Upper Carboniferous (Kasimovian–Gzhelian) to Lower–Middle Permian (Asselian–Roadian) (see OKUYUCU et al., 2018 for a brief review). Within this metamorphosed succession, Carboniferous rock units are represented by dark-coloured, fine-grained clastic rocks of Tournaisian–Viséan age and platform carbonates of Viséan–Moscovian age (ÖZGÜL, 1997; OKUYUCU et al., 2018).

The Viséan–Moscovian foraminiferal evidence from the Bolkar Dağı Nappe is quite restricted due to the absence of detail biostratigraphic studies performed on this time interval. Whereas some foraminiferal assemblages were reported by ÖZGÜL (1997), a detailed subdivision or foraminiferal biozonation was not established in this study. Therefore, it is difficult to correlate the foraminiferal biozonation or assemblages defined in this study with the foraminiferal data from the Bolkar Dağı Nappe. Nevertheless, there are some foraminiferal taxa recovered from the Bolkar Dağı Nappe which are similar to those within this study, such as *Millerella* spp., '*Biseriella*' *parva*, *Neoarchaediscus* spp., *Asteroarchaediscus* spp., *Eostaffella* spp., *Endothyra* spp., etc., reported by ÖZGÜL (1997) without their chronostratigraphic range.

6.1.3. The Beyşehir–Hoyran Nappes

The Beyşehir–Hoyran nappes is a crucial tectonostratigraphic unit in the Taurides with peculiar stratigraphic properties (BRUNN et al., 1970, 1971; ÖZGÜL, 1984; TEKİN et al., 2016a, b). The Beyşehir–Hoyran nappes are subdivided into four structural units, including the Boyalıtepe unit of Late Triassic–Late Cretaceous age, the Huğlu unit of Middle Triassic-Late Cretaceous age, the Gencek unit of Triassic age, and the Peridotite unit of possibly Cretaceous age (BRUNN et al., 1970, 1971; GUTNIC et al., 1979). According to the recent studies performed on the Mersin Mélange as a part of the Beyşehir–Hoyran Nappes (TEKİN et al., 2016a, b, 2020), it was suggested that the Beyşehir–Hoyran Nappes is a sedimentary mélange including blocks and tectonic slices of different ages, (e.g., late Tournaisian to Turonian) and various origins (platform and basin) within a clastic matrix of Late Cretaceous age (see detailed review by OKUYUCU et al., 2024).

To the east of Taşkent city, rock units of the Mersin Mélange were studied in detail by OKUYUCU et al. (2024) for the foraminiferal biochronology of upper Serpukhovian strata in the Kösürelik-1 section. This section is composed of carbonate-dominated rock units similar to the Kapaklı section (Fig. 17). However, the coeval strata of these two sections are represented by different marker foraminiferal taxa. The uppermost part of the Kapaklı section includes the potential marker *Eostaffellina paraprotvae* for this interval, while the Kösürelik-1 section is characterized by the age-diagnostic taxon *Monotaxinoides transitorius* BRAZHNIKOVA & YARTSEVA, 1956, clearly revealing the latest Serpukhovian age (KULAGINA et al., 2003, 2008, 2009).

OKUYUCU et al. (2018) reported the presence of a small carbonate-dominated Bashkirian block in the Mersin Mélange (southern Türkiye) (Fig. 17). This block includes some significant foraminiferal taxa *Pseudostaffella praegorskyi* RAUSER-CHERNOUSOVA, 1949 and *Varistaffella ziganica* (SINITSYNA in GROZDILOVA et al., 1975), indicating the upper part of the lower Bashkirian (Askynbashian). Although the assemblage obtained from the Mersin Mélange of the Beyşehir–Hoyran nappes and the Bashkirian assemblage obtained in this study are different, rock units from the same time interval are present in both oceanic branches (IAE and Intra-Pontide) of the Northern Neotethys.

6.2. Correlation to the Previously Described Carboniferous Blocks Within the Elmadağ Olistostrome Over the Sakarya Composite Terrane

Carboniferous blocks in the Elmadağ Olistostrome were previously accepted by numerous studies as representing part of the Triassic Upper Karakaya Complex until the recent finding of Jurassic and Cretaceous radiolarians within this unit (TEKİN et al., 2025). Therefore, the Elmadağ Olistostrome cannot be regarded as a Palaeotethyan-related unit, but instead it appears to represent foreland flysch deposits of the Intra-Pontide Ocean (see TEKİN et al., 2025 for brief review), extending over a wide region from the Biga peninsula (NW Türkiye) to the Ankara region (central Türkiye) (e.g., KAHLER & KAHLER, 1979; AKYÜREK et al., 1982, 1984; OKAY et

al., 1990, 1991; LEVEN & OKAY, 1996; ALTINER et al., 2000; PILLE et al., 2010; DURU et al., 2012) (Fig. 18).

A Middle Carboniferous block including *Pseudostaffella* sp., *Ozawainella* cf. *vozhgalica* SAFONOVA in RAUSER-CHERNOUSOVA et al., 1951, *Fusulina* cf. *mosquensis* RAUSER-CHERNOUSOVA in RAUSER-CHERNOUSOVA et al., 1951, *Pseudoendothyra pseudosphaeroida* (DUTKEVICH, 1934a) foraminiferal taxa was reported by KAHLER & KAHLER (1979), in the Balya–Edremit region from the Biga peninsula (NW Türkiye). According to the re-evaluation of this foraminiferal assemblage, the age of this block is assigned to the middle-late Moscovian herein (Fig. 18).

Some Carboniferous blocks from the Hodul and Orhanlar Greywacke units from the Biga peninsula (NW Türkiye) have been reported by OKAY et al. (1990, 1991). Based on the re-evaluation of the foraminiferal assemblages reported in that study, these blocks should be considered as latest Serpukhovian and late Moscovian in age (Fig. 18). Although the characteristic latest Serpukhovian foraminiferal taxon *Monotaxinoides transitorius* was not recovered from the upper part of the Kapaklı section, a similar foraminiferal assemblage (e.g., *Endothyra*, *Bradyina*, *Archaediscus* and *Monotaxinoides*) was described both in OKAY et al. (1990, 1991) and in the present study.

LEVEN & OKAY (1996) described numerous blocks ranging from Viséan to ?Gzhelian in age from the Biga peninsula (NW Türkiye) (Fig. 18). The Serpukhovian block defined by LEVEN & OKAY (1996) contains a typical early Serpukhovian foraminiferal assemblage (e.g., *Eostaffella ikensis* VISSARIONOVA, 1948 and *Biseriella parva*) that is similar to the described taxa in the *Neoarchaediscus postrugosus–Biseriella parva* Assemblage Zone (lower Serpukhovian) within the Kapaklı section and provides a good correlation. The foraminiferal assemblage of the Bashkirian block studied by LEVEN & OKAY (1996) was dated as an early substage of the Bashkirian based on the co-occurrence of *Pseudostaffella antiqua* (DUTKEVICH, 1934b), *Eostaffella* sp. and *Neoarchaediscus* sp. As a result of re-evaluation of the foraminiferal assemblage of the Bashkirian block defined by LEVEN & OKAY (1996), its age can be assigned as late Early Bashkirian (Akavasian substage), based on the occurrence of the *Pseudostaffella antiqua* compared to the previous studies (e.g., KULAGINA et al., 2000, 2001; ORLOV-LABSOVSKY et al., 2007; LEVEN & GORGIJ, 2011; AKBAŞ & OKUYUCU, 2022). The age of the block assigned a ?Gzhelian age by LEVEN & OKAY (1996) is doubtful because of its long-ranging fusulinid taxa (Fig. 18). As indicated by LEVEN & OKAY (1996), the characteristic uppermost Gzhelian specimen *Daixina* (*Ultradaixina*) *postgallowayi* BENSH, 1962 was originally described from the Sakmarian of North Fergana (BENSH, 1962). Additionally, the *hovunensis*-type pseudofusulinids are also commonly found in Lower Permian strata. The doubtful description of the genera *Alpinoschwagerina* and *Triticites* supports the confusion about the age of this single ?Gzhelian block.

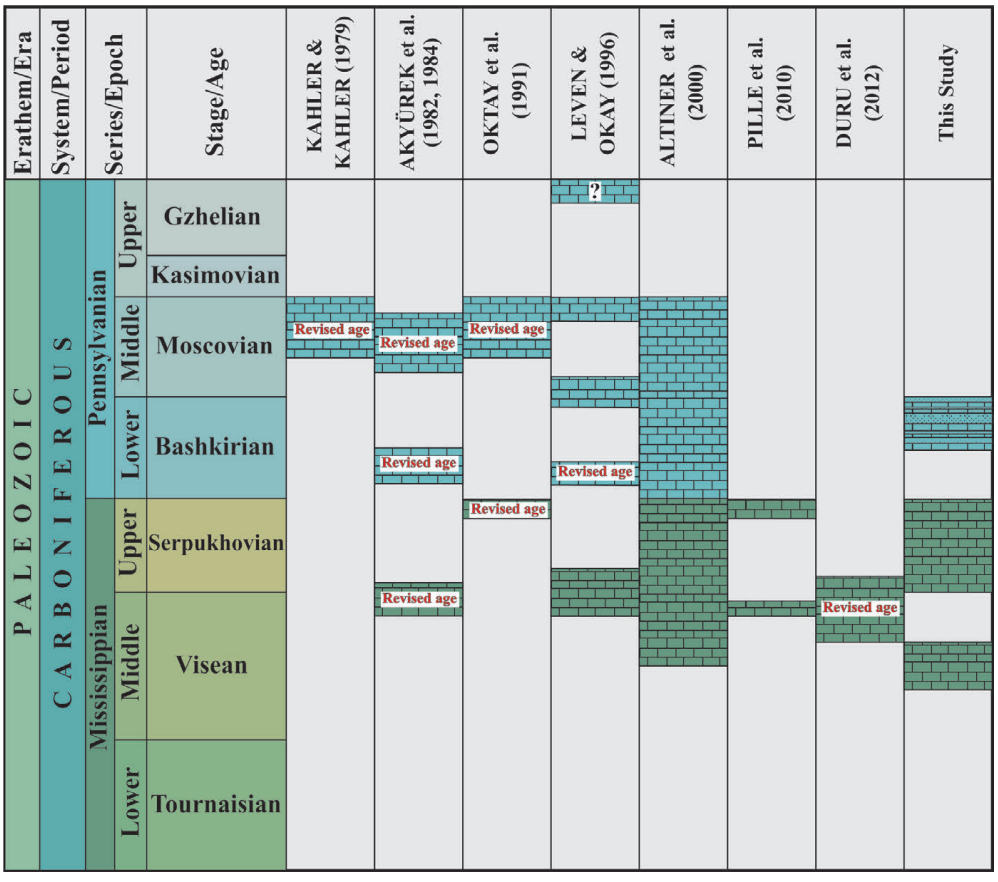

Figure 18. Correlation of the Carboniferous blocks/slices in the Upper Cretaceous Elmadağ Olistostrome which originated from the Intra-Pontide Ocean, which was previously assigned to the Karakaya Complex

ALTINER et al. (2000) reported some Carboniferous blocks (ranging in age from the late Viséan to the Moscovian) within the olistostromal units from the Balıkesir and Bursa regions (NW Türkiye), without any palaeontological data (Fig. 18). Therefore, no correlation could be realized.

PILLE et al. (2010) reported from the Biga peninsula (Balya–Maden, NW Türkiye), a rich and diverse calcareous algae assemblage associated with poor foraminiferal fauna from late Viséan and late Serpukhovian olistoliths (Fig. 18). Since the foraminiferal fauna obtained by PILLE et al. (2010) is very poor and different from our recovered assemblage from the same stratigraphic levels, it is not possible to realize a good and precise correlation.

DURU et al. (2012) reported foraminiferal taxa (e.g., *Mediocris* ex gr. *mediocris*, *Archaediscus* sp., *Eolasiodiscus* sp., *Neoarchaediscus*? sp., *Pseudoendothyra* sp., *Monotaxinoides*? sp., *Omphalotis* sp., *Tuberitina* sp. and *Eotuberitina* sp.) of Viséan–Serpukhovian (Early Carboniferous) age, from a small block in the Biga peninsula (NW Türkiye). According to re-evaluation of this foraminiferal assemblage, based on the first occurrence of *Eolasiodiscus*, *Neoarchaediscus* and *Monotaxinoides* (KULAGINA & FILIMONOVA, 2020), and the lack of index Serpukhovian foraminiferal taxa (e.g., *Neoarchaediscus postrugosus, Biseriella parva*), the age of this block was assigned to the late Viséan–earliest Serpukhovian? herein. Even though some common foraminiferal taxa are present both in the Kapaklı section and DURU et al.'s (2012) material, it is not possible to make a precise correlation.

In the study of AKYÜREK et al. (1982, 1984), a great number of blocks were sampled from the Elmadağ Olistostrome in the Ankara region for dating. Even though there are many studied samples, the age of the blocks mainly indicates similar time intervals (AKYÜREK et al., 1982, 1984). The re-evaluation of the fossil assemblages reported by AKYÜREK et al. (1982, 1984) reveals that these blocks are of late Viséan–earliest Serpukhovian?, late Early Bashkirian, and middle Moscovian in age, respectively (Fig. 18). Early Carboniferous ages from the blocks reported by AKYÜREK et al. (1982, 1984) include long-ranging taxa, and it is not possible to realize a correlation with the Kapaklı section due to the lack of index Serpukhovian taxa.

7. DISCUSSION AND CONCLUSION

To understand the characteristics of the Carboniferous blocks in the Elmadağ Olistostrome, exposures to the north and east of Ankara city were studied in detail (Fig. 2). Based on studies on the Kapaklı region (northeast of Ankara city), Taşönü region (east of Ankara city), and Yakupabdal region (southeast of Ankara city), rich Carboniferous foraminiferal assemblages were recovered from two stratigraphic sections (Kapaklı and Sapankıran) and two isolated carbonate samples (21-EL-06 and 21-EL-41).

The isolated sample 21-EL-41 of middle Viséan age from the Kapaklı region could only be correlated with Viséan rock units of the Hadim Nappe from the IAE Ocean in the Taurides, which are both represented by shallow marine platform carbonates with some similar characteristic middle Viséan taxa (GÜVENÇ, 1965, 1977; ÖZGÜL, 1997; AKBAŞ, 2024) (Fig. 17). The isolated sample 21-EL-06 of early Serpukhovian age from the Taşönü region could also only be correlated with the typical earliest Serpukhovian foraminiferal fauna of the Hadim Nappe (ALTINER & ÖZGÜL, 2001; DEMİREL & ALTINER, 2016) (Fig. 17).

The Kapaklı section taken from a carbonate-dominated mega-block in the Kapaklı region is represented by a rich and diverse foraminiferal fauna. This unique foraminiferal assemblage obtained from the Kapaklı section allowed subdivision of the Serpukhovian sequence into three local biozones, namely the lower Serpukhovian *Neoarchaediscus postrugosus – Biseriella parva* Assemblage Zone and the upper lower Serpukhovian *Eostaffellina decurta* Zone and the upper Serpukhovian Eostaffellina paraprotvae Zone. The sequence and foraminiferal assemblage of the Kapaklı section are correlated with coeval successions from the Hadim Nappe and the Beyşehir–Hoyran nappes from the Izmir–Ankara–Erzincan Ocean (Fig. 17). While the sequence of the Kapaklı section with abundant and diverse Serpukhovian foraminiferal taxa is fully represented by platform carbonates without siliciclastic input, the sequence of the Hadim Nappe from the IAE Ocean includes basically siliciclastics with poor and incomplete foraminiferal taxa from the same time interval (ÖZGÜL, 1997; ALTINER & ÖZGÜL, 2001). The Serpukhovian strata of the Beyşehir–Hoyran nappes (Kösürelik-1 section in the central Taurides) also consist of carbonate-dominated rock units like the Kapaklı section (OKUYUCU et al., 2024).

Based on the evaluation of the foraminiferal assemblage obtained from the Sapankıran section of a late Early–late Bashkirian age from the Yakupabdal region, its characteristics are well-correlatable to the sequence and foraminiferal fauna of the Hadim Nappe from the IAE Ocean (ÖZGÜL, 1997; DZHENCHURAEVA & OKUYUCU, 2007; AKBAŞ & OKUYUCU, 2021) (Fig. 17).

Due to the highly restricted foraminiferal evidence related to the effects of metamorphism and the presence of multiple hiatuses in the coeval rock units in the Bolkar Dağı Nappe from the IAE Ocean, it is not possible to correlate them to the Carboniferous blocks in this study. Upper Pennsylvanian and Lower Permian successions in the Bolkar Dağı Nappe are not present, and carbonates of Middle Permian age rest unconformably on the Moscovian sequence (ÖZGÜL, 1997). This sedimentation break including the Upper Pennsylvanian and Lower Permian sequences are also common features of other northerly originated nappe packages from the IAE Ocean in the Taurides except for the Hadim Nappe. This sedimentation gap has occurred due to a glaciation event affecting the northern Gondwana region and the mantle plume occurrence causing major uplift at the Northern Neotethys Oceans (OKUYUCU et al., 2018, 2024; TEKİN et al., 2019). Critical evidence supporting the existence of possible uplift during the Pennsylvanian and Early Permian that affected both the Intra-Pontide and the IAE oceans (e.g., Bolkar Dağı and Beyşehir–Hoyran nappes), is the absence of Middle–Upper Pennsylvanian deposits in the studied sequences from the Intra-Pontide Ocean (Fig. 18).

Based on the correlations to units of the Tauride–Anatolide Platform composed mainly of nappe packs from the IAE

Ocean, it can be suggested that there was a limited faunal exchange between the Sakarya Composite Terrane and the Tauride–Anatolide Platform during the Carboniferous. This could have been due to the paleogeographic position of the Sakarya Composite Terrane during the Early Carboniferous being closer to the southern margin of Laurasia compared to the position of the Tauride–Anatolide Platform (OKUYUCU et al., 2013; Fig. 14). This idea is supported by the presence of similar foraminiferal assemblages and their close FOD's between the Sakarya Composite Terrane (this study) and the Russian Platform (Moscow Basin by KULAGINA & GIBSMAN, 2002; KULAGINA et al., 2003; KABANOV et al., 2016). According to the subdivision of dispersal routes proposed by CÓZAR et al. (2019), the Sakarya Composite Terrane is probably located at the southern dispersal branch where the displacements of the foraminifers occurred more rapidly than via the northern migration route for the foraminifers during the Viséan-Serpukhovian.

Another issue to be considered is that the limestone blocks within the Elmadağ Olistostrome were previously regarded to be preserved within the Karakaya Complex, believed to be the subduction/accretion complex of the Palaeotethys. This, in turn, inevitably brought the idea that the limestone blocks were derived from either the northern or southern margin of Palaeotethys. Thus, the source region of the blocks was sought in the Laurasian and/or Anatolide–Tauride margin, with more emphasis on the latter. Based on the greater Gondwanan affinity of the blocks, LEVEN & OKAY (1996) suggested a south-to-north transportation direction for the blocks. However, in light of the new evidence (TEKİN et al., 2024, 2025; SAYİT et al., 2026), since the so-called Triassic Upper Karakaya Complex is mainly a Cretaceous melangé derived from the Intra-Pontide realm, there appears now to be no Triassic melangé that preserved the Palaeotethyan fragments. This implies that the melangé, namely the Elmadağ Olistostrome, that carries the Carboniferous blocks, is of Neotethyan (Intra-Pontide Ocean) origin. This result is crucial since it eliminates Palaeotethys as the oceanic domain between the inferred sources of carbonate-bearing margins. This, in turn, disregards the Laurasian margin as the source region and may suggest another Gondwanan-related margin(s) to the north of the TAP instead. This result may allow a better understanding of why somewhat similar characteristics are found in the blocks within the Elmadağ Olistostrome and those from the TAP.

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