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New age data from the tectonostratigraphic units of the Istranca "Massif" in NW Turkey: a correlation with SE Bulgaria

YAVUZ BEDİ [1], EMIL VASILEV[2], CHRISTO DABOVSKI[2], ALİ ERGEN[1], CENGİZ OKUYUCU[1], ADİL DOĞAN[1], U. KAĞAN TEKİN[3], DARIA IVANOVA[2], ILIANA BONCHEVA[2], ISKRA LAKOVA[2], VALERI SACHANSKI[2], İSMAİL KUŞCU[1], ERCAN TUNCAY[1], D. GÜLNUR DEMİRAY[1], HAVVA SOYCAN[1] and M. CEMAL GÖNCÜOĞLU[4]

[1]General Directorate of Mineral Research and Exploration (MTA), Department of Geological Research, Ankara; yavuzbedi@gmail.com; okuyucucengiz@gmail.com
[2]Bulgarian Academy of Sciences, Institute of Geology, Sofia; cdabovski@yahoo.com; v-sachanski@geology.bas.bg;
[3]Hacettepe University, Department of Geological Engineering, Ankara; uktekin@yahoo.com
[4]Middle East Technical University, Department of Geological Engineering, Ankara; mcgoncu@metu.edu.tr

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Abstract: The Istranca Crystalline Complex in NW Anatolia and SE Bulgaria includes structural units that differ in lithostratigraphy, metamorphism, age and structural position. They are collectively named as the "Istranca nappes" comprising from bottom to top the Sarpdere, Mahyadağ and Doğanköy Nappes. The Sarpdere Nappe consists of Lower Triassic arkosic metasandstones with slate interlayers, followed by Middle to Upper Triassic carbonates and an alternation of Upper Triassic clastics and carbonates. The Mahyadağ Nappe comprises a low-grade metamorphic Late Paleozoic–Triassic carbonate-siliciclastic sedimentary succession. The Doğanköy Nappe includes Precambrian?–Paleozoic metasediments, intruded by Late Carboniferous-Early Permian calc-alkaline granitoids. Its Triassic cover comprises metaclastics and metacarbonates. The Istranca nappes were juxtaposed at the end of the Triassic and transgressively covered by Lower Jurassic coarse clastics, followed above by Middle to Late Jurassic carbonates, black shales and carbonate-siliciclastic sedimentary succession. The phosphate concretions in black shales yielded radiolarian assemblages indicating Late Bajocian-Early Bathonian, Early Bathonian and Early Kimmeridgian ages. These nappes and their Jurassic cover are unconformably overlain by the Cenomanian-Santonian volcano-sedimentary successions intruded by Santonian-Campanian Dereköy-Demirköy intrusive suite. The preliminary data suggest that the Variscan basements of the Mahyadağ and Sarpdere Nappes were juxtaposed prior to the Triassic and overridden by the Doğanköy Nappe of possible Rhodopean origin from S to N during the Cimmerian compressional events.

Key words: NW Turkey, SE Bulgaria, Istranca Crystalline Complex, stratigraphy, nappes.

Introduction

The Istranca (Strandja, Strandzha) "Massif" is a NW-SE trending, almost 300 km long and 40 km wide Alpine unit that straddles across the Turkish-Bulgarian border in southeastern Balkan Peninsula (Figs. 1, 2 inset map). To the north, it is bounded by a main thrust zone along which the "Massif" is emplaced onto the volcano-sedimentary and igneous rocks of the Late Cretaceous Srednogorie Zone. The southern boundary is covered by the 10 km thick Tertiary sediments of the Thrace (Trakya) Basin. The contact with the Rhodope Unit, the other main crystalline unit of the Balkan Peninsula, is covered by the western continuation of the Thrace Basin.

Apart from a few recent studies on the Bulgarian (Dabovski et al. 2002) and the Turkish side (Okay et al. 2001; Elmas et al. 2010) the tectonic units, their stratigraphy as well as their structural relations are not known to the international community. Even if there are some detailed studies on lithostratigraphy (e.g. Ksiazkiewicz 1930; Aydın 1982; Çağlayan 1996; Çağlayan & Yurtsever 1998 in the Turkish side, and Chatalov 1980, 1988, 1990; Gocev 1985; Dabovski & Savov 1988; Gerdjikov 2005a; Vasilev & Dabovski 2010 in the Bulgarian side), they are mostly in native languages and hardly available. Moreover, no correlation is available on the structural and lithostratigraphic units, and the available small-scale geological maps for the Bulgarian (Cheshitev & Kancev 1989) and Turkish (Çağlayan & Yurtsever 1998) side of the "Massif" do not match. To overcome these shortcomings and achieve a better understanding of the disputed geological evolution of this less-known area, teams from the General Directorate of Mineral Research and Exploration (MTA) and the Geological Institute of the Bulgarian Academy of Sciences have started in 2009 a bilateral mapping and correlation project along the Bulgarian-Turkish border. The present paper includes the new findings on the biostratigraphy, structural relations as well as a correlation of the rock units in both areas. The stratigraphic nomenclature in this paper is applied in a way that only the Bulgarian names are used for formations with type localities in Bulgaria, whereas Turkish names (with the Bulgarian ones in brackets) are used if their type sections are established in Turkey. A correlation chart of the very complicated nomenclature is given in

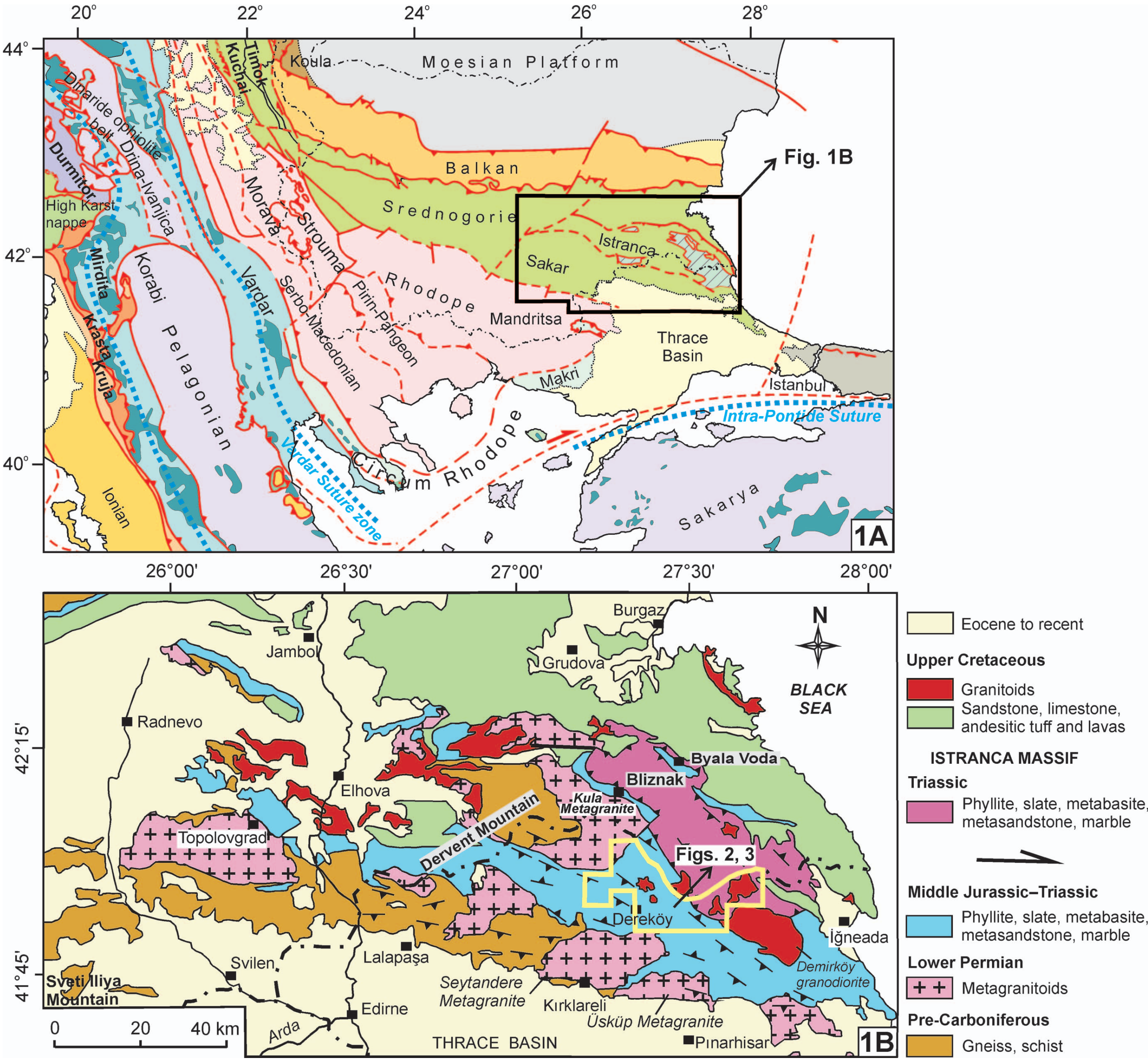

Fig. 1. Tectonic setting and geological map of Istranca Crystalline Complex. **A** — Alpine tectonic setting of the Balkan Peninsula (after Dabovski & Zagorchev 2009), **B** — Geological map of the Istranca "Massif" and the neighbouring regions (Okay et al. 2001).

Table 1. The corresponding lithostratigraphic units and their names are marked in the explanations of Fig. 3 and related columnar sections in Figs. 5, 7, 8 and 9.

Regional geology

In the Turkish side of the Istranca "Massif" the pre-Late Jurassic overall stratigraphic picture based on previous data is a pre-Triassic metamorphic basement intruded by Upper Paleozoic metagranitoids/orthogneisses, unconformably overlain by Triassic-Jurassic cover rocks (Aydın 1974, 1988; Aykol 1979; Üşümezsoy 1982, 1990; Okay et al. 1995; Göncüoğlu et al. 1997; Çağlayan & Yurtsever 1998; Natal'in et al. 2005; Okay & Yurtsever 2006). The basement together with the sedimentary cover was intensely imbricated by north-verging thrusts probably during the Late Jurassic–Early Cretaceous, accompanied by a regional metamorphism affecting the whole "Massif" (Okay et al. 2001). Actually, it has already been known since the 1930's (e.g. Ksiazkiewicz 1930) that a napped structure is present in the Istanbul, Istranca and Sakar regions. This was further confirmed by Şengör et al. (1984)'s definition of the Kırklareli and Istranca nappes and Okay et al. (2001)'s recognition of several north-vergent structural units as products of thick-skinned tectonics. This structural model was also the basis of the later geodynamic interpretations (e.g. Okay et al. 2001; Sunal et al. 2006; Elmas et al. 2010).

In the Bulgarian part, however, the presence of coeval successions with completely different formal lithostratigraphy was recognized and attributed to long-distance-travel by al-

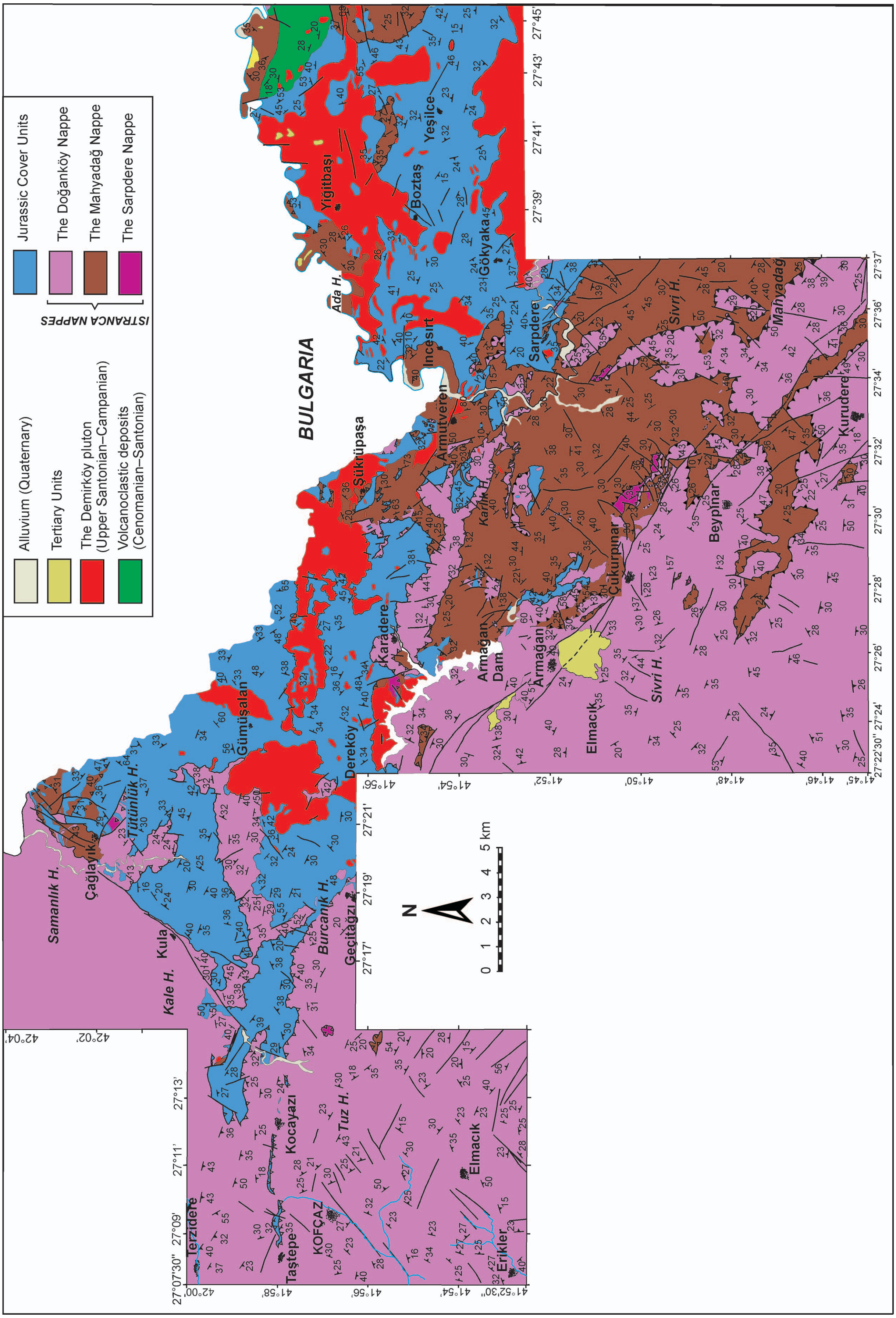

Fig. 2. Structural map of the Istranca Crystalline Complex (western part).

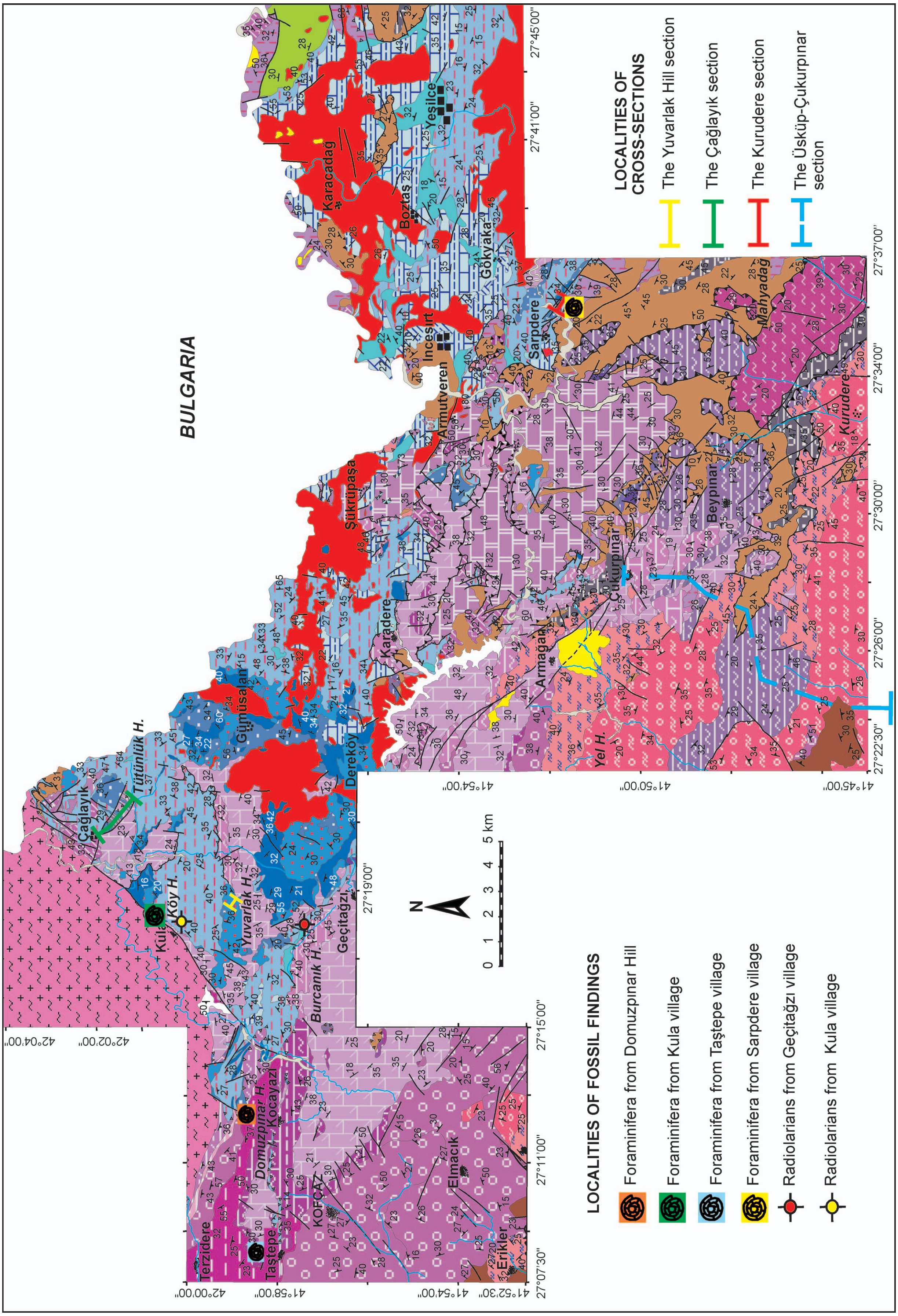

Fig. 3. Geological map of Istranca Crystalline Complex for the Turkish side. *The legend is on the next page.*

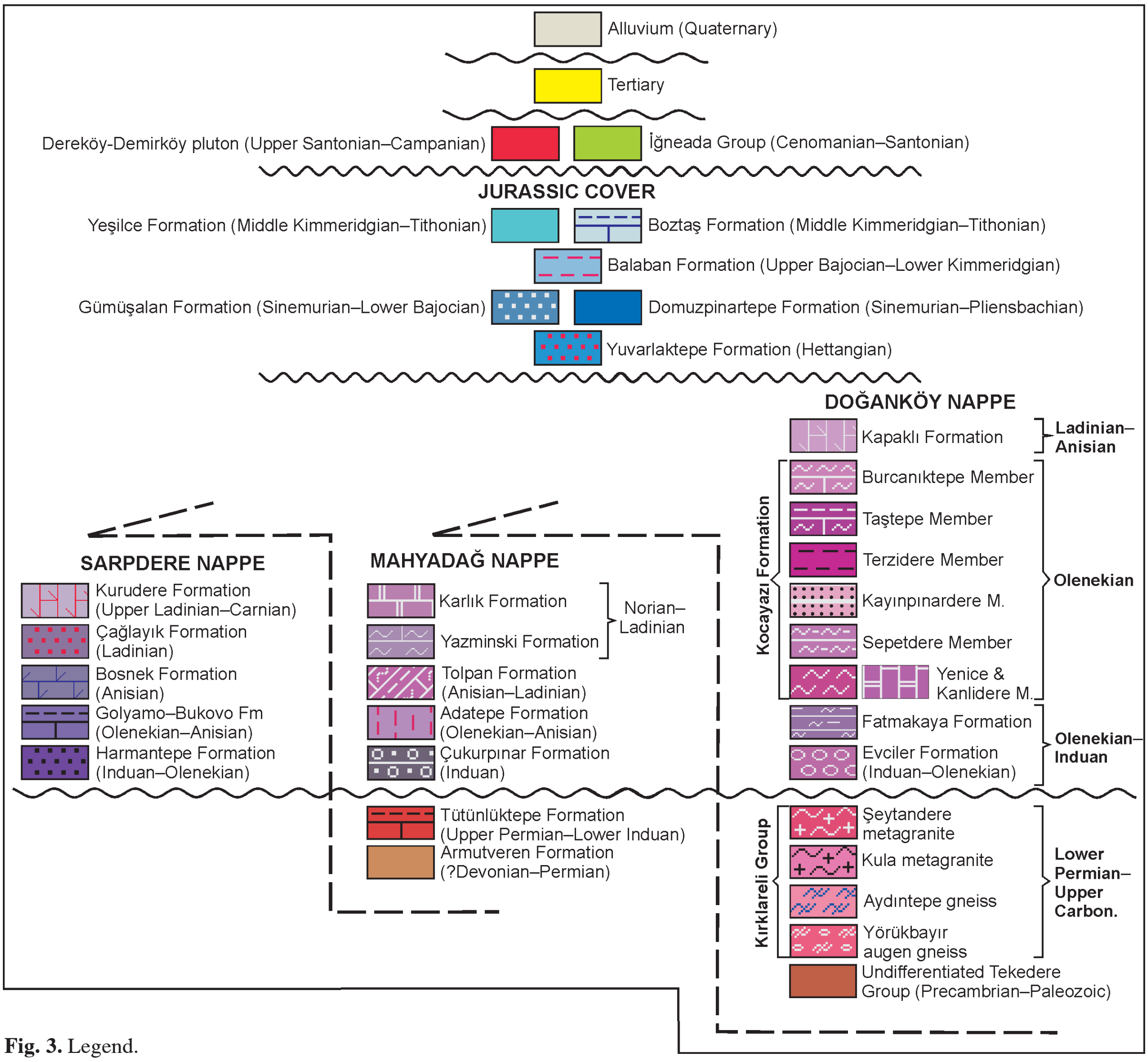

Fig. 3. Legend.

lochthonous bodies or nappes (e.g. Chatalov 1980, 1985, 1988, 1990; Dabovski & Savov 1988; Dabovski et al. 1990, 2002). In the Dervent and Sveti Ilia Highs (Gocev 1985, 1991; Gerdjikov 2005b) and in Bulgarian Istranca (Chatalov 1980, 1985; Dabovski & Savov 1998; Dabovski et al. 1990, 2002; Gerdjikov 2005a) these nappes were described in considerable detail. In E Bulgaria, Yanev et al. (2006) also recognized that some greenschist metamorphic Paleozoic rocks within the Alpine allochthonous units are thrust over Triassic-Jurassic rocks.

Previous tectonic scenarios (e.g. Chatalov 1980, 1985, 1988; Okay et al. 2001; Dabovski et al. 2002; Sunal et al. 2011) assume that the juxtaposition of the tectonic units in Istranca was the result of Late Jurassic–Early Cretaceous compression.

The recent detailed mapping along the Turkish-Bulgarian border (Fig. 3), presented in this study showed the presence of at least three nappes and slices of them in thrust contact with each other on the Turkish side. They completely differ in stratigraphy (Fig. 4), lithology and metamorphic features (Bedi et al. 2011a). These structural units in Turkey are hereafter called the Istranca nappes. They include in ascending order the Sarpdere, the Mahyadağ, and the Doğanköy Nappes. Considering their Triassic lithostratigraphy, they correspond to the Subbalkanide type, the Strandja type, and the Sakar type nappes of Chatalov (1980), respectively. Based on the new data from the Turkish side, these three nappes are sealed by Lower Jurassic clastics. The Jurassic overstep sequence, on the other hand, is completely revised by this study on the basis of new fossil data obtained from different nappes. The details of the Upper Cretaceous volcano-sedimentary successions are beyond the scope of this paper and will be only evaluated briefly.

The Cimmerian Istranca Nappes

The lithostratigraphy, metamorphism and structural position of the Triassic rocks are the main criteria to differentiate the Istranca nappes. Therefore, we will emphasize the stratigraphy and lithology of the Triassic rocks in the Turkish and Bulgarian parts of the Istranca "Massif". The ages of the

Table 1: Correlation chart of the lithostratigraphic units in Bulgaria and Turkey.

Subbalkanide type Triassic (Chatalov 1980)	**Sarpdere Nappe (Bedi et al. 2011a,b)**
Pitovo Fm (Chatalov 1985)	Harmantepe Fm (Bedi et al. 2011a,b)
Golyamo Bukovo Fm (Chatalov & Trifonova 1985)	Golyamo Bukovo Fm
Bosnek Fm (Tronkov, 1975)	Bosnek Fm
Lepen Member (Chatalov 1984)	Çağlayık Fm (Bedi et al. 2011a,b)
Troyan Fm (Chatalov 1984)	Kurudere Fm (Bedi et al. 2011a,b)
Ambaritsa Fm (Chatalov 1984)	Ambaritsa Fm
Strandja type Triassic (Chatalov 1980)	**Mahyadağ Nappe (Bedi et al. 2011a,b)**
Zaberska Fm (Chatalov 1985)	Armutveren Fm (Bedi et al. 2011a,b)
Struvnitsa Member (Chatalov 1985)	Çukurpınar Fm (Bedi et al. 2011a,b)
Kushliovo Fm (Vasilev 1998)	Lower part of Adatepe Fm (Bedi et al. 2011a,b)
Gramatikovo Fm (Chatalov 1985)	Upper part of Adatepe Fm (Bedi et al. 2011a,b)
Tolpan Fm (Vasilev 2001)	Tolpan Fm
Kalinachuka Fm (Vasilev 2001)	Kalinachuka Fm
Yazminski Fm (Vasilev 2001)	Yazminski Fm
Malko Tarnovo Fm (Chatalov 1983, 1985)	Karlık Marble Member (Çağlayan & Yurtsever 1998), Karlık Marble (Okay & Yurtsever 2006), Karlık Fm (Bedi et al. 2011a,b)
Sakar type Triassic (Chatalov 1980)	**Doğanköy Nappe (Bedi et al. 2011a,b)**
Zhaltychal Fm (Kozhoukharov 1987)	Tekedere Group (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006)
Lessovo Metagranitoid (Kamenov et al. 1986; Vergilov et al. 1986)	Kırklareli Metagranite (Aydın 1974, 1982), Kırklareli Group (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006)
Sakar Pluton (Vergilov et al. 1986)	Hamzabeyli Metagranite (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006)
Paleokastro Fm (Chatalov 1980)	Evciler Gneiss (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006), Evciler Fm (Bedi et al. 2011a,b), Caferintaşları Metaconglomerates Member (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006)
	Fatmakaya Gneiss (Pamir & Baykal 1947), Fatmakaya Fm (Çağlayan & Yurtsever 1998; Bedi et al. 2011b)
Ustrem Fm (Chatalov 1985)	Kocayazı Fm (Bedi et al. 2011b)
Kerimarski Member (Chatalov 1985)	Yenice Member (Çağlayan & Yurtsever 1998)
Mramor Member (Chatalov 1985)	Kanlıdere Member (Bedi et al. 2011b)
Chanaklı Member (Chatalov 1985)	Sepetdere, Kayınpınardere, Terzidere, Taştepe and Burcanıktepe Members (Bedi et al. 2010a,b), Terzidere Clayey Schist Member (Çağlayan & Yurtsever 1998), Terzidere Fm (Okay & Yurtsever 2006), Taştepe Phyllite Chalcschist Member (Çağlayan & Yurtsever 1998), Taştepe Chalkschist (Okay & Yurtsever 2006), Çukurpınar Chalkschist Member (Çağlayan & Yurtsever 1998), Çukurpınar Chalkschist (Okay & Yurtsever 2006)
Srem Fm (Chatalov 1985)	Kapaklı Member (Çağlayan & Yurtsever 1998), Kapaklı Dolomite (Okay & Yurtsever 2006) Kapaklı Fm (Aydın 1988; Bedi et al. 2011a,b)
Jurassic Cover Units	
Kostina Fm (Sapunov et al. 1967), Kubarelov Quartzitic Fm (Chatalov 1985)	Yuvarlaktepe Fm (Bedi et al. 2011a,b)
Ozirovo Fm (Sapunov et al. 1967), Kraynovo Fm (Chatalov 1985)	Domuzpınartepe Fm (Bedi et al. 2011a,b)
Bliznak Fm (Chatalov 1985)	Gümüşalan Fm (Bedi et al. 2011a,b)
Zvezdets Fm (Chatalov 1985)	Balaban Member (Çağlayan & Yurtsever 1998), Balaban Fm (Okay & Yurtsever 2006; Bedi et al. 2011a,b)
Kazanska Member (Chatalov 1985)	Uzundere Member (Bedi et al. 2011a,b)
Brashlyan Fm (Chatalov 1985)	Boztaş Fm (Bedi et al. 2011a,b)
Hranova Fm (Chatalov 1985)	Balcıtepe Fm (Bedi et al. 2011a,b), Yeşilce Fm

lithostratigraphic units, the most critical issue in this study, are partly new findings we recently obtained during this study, but are also supported by published (mainly in Bulgarian language) and unpublished studies for the Bulgarian side. Considering that these structural units were initially imbricated prior to the Liassic as a result of Cimmerian events they are named the "Cimmerian Istranca Nappes (CIN)".

The Sarpdere Nappe

This unit is structurally the lowermost one in the Istranca tectonic belt. Its pre-Triassic basement is not exposed in Turkish part whereas it is thrust onto the other structural units (Fig. 5).

The succession in the Bulgarian part is represented by a pre-Triassic basement, covered unconformably by Triassic (Subbalkanide type Triassic, Chatalov 1980) and Jurassic sediments, which were considered to form the autochthonous basement of the CIN (e.g. Chatalov 1980; Dabovski et al. 1990; Vasilev & Dabovski 2010). The pre-Triassic sequences in the Bulgarian part show some differences. For example, the Paleozoic sequence to the north of Topolovgrad (Fig. 5, column B) comprises a metaclastic-dominated succession with volcanic and volcaniclastic intervals (Chatalov 1983, 1985), whereas to the east of Golyamo Bukovo and south-west of Zvezdets the Triassic sediments are tectonically underlain by Carboniferous-Permian granitoids.

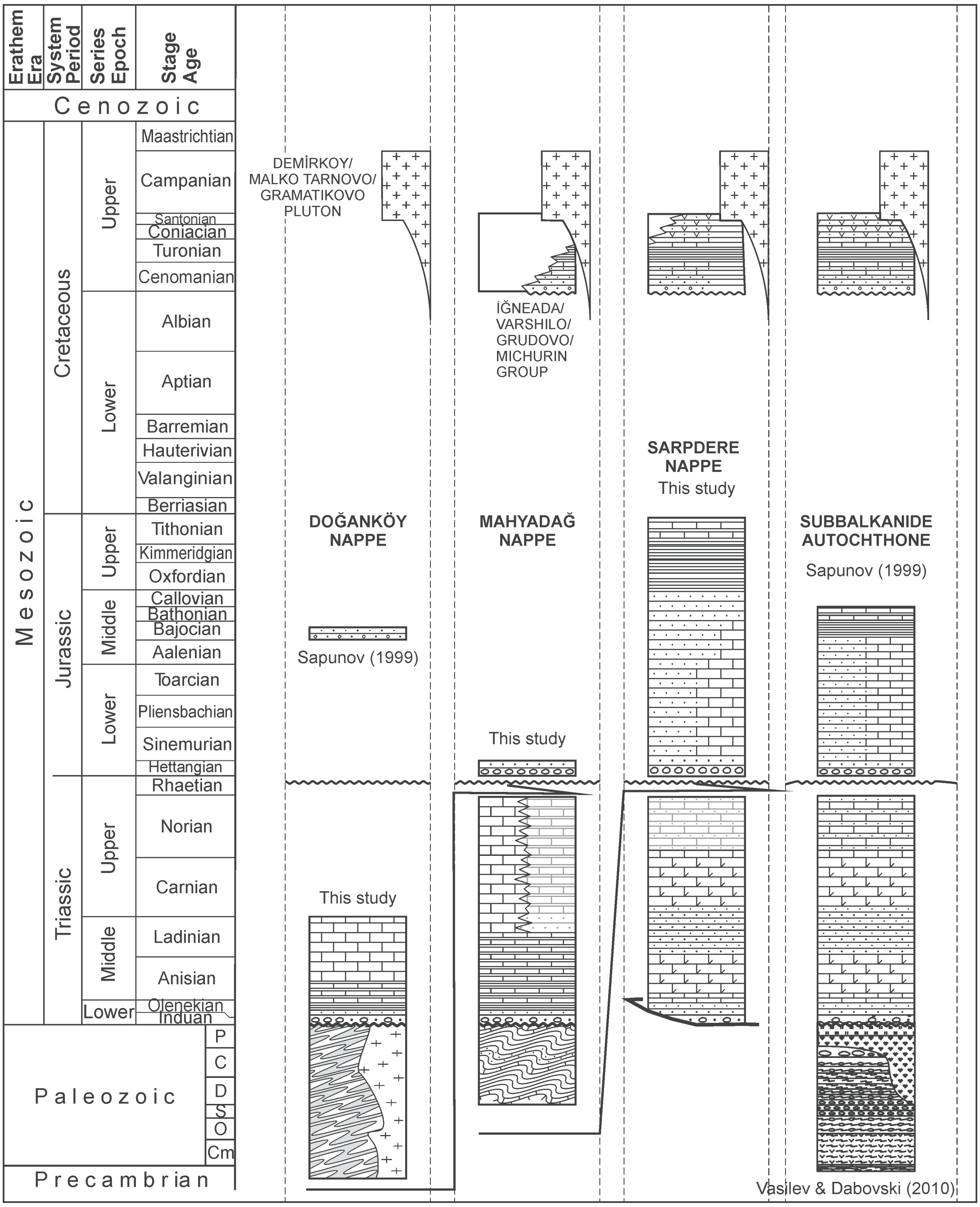

Fig. 4. Correlation chart of the tectonostratigraphic units in the Istranca Crystalline Complex (Istranca “Massif”).

The Triassic succession of the Sarpdere Nappe displays similarities along the Istranca belt on both sides of the Turkish-Bulgarian border. It mainly crops out in the S of the recently re-mapped area shown in Figure 3. In the Turkish part, from bottom to top, the sequence comprises (Fig. 5) the following formations: arkosic metasandstone, metasiltstone, metamudstone alternations of the Lower Triassic (Induan–Olenekian) Harmantepe Formation (the Pitovo Formation of Chatalov 1985); the Olenekian-Anisian Golyamo Bukovo Formation (Chatalov & Trifonova 1985) including dolomite, dolomitic limestone and recrystallized limestone with greyish-pinkish colour, locally thin- to thick-bedded metasandstone and metasiltstone interbeds; the Anisian Bosnek Formation (Tronkov 1975) with micritic dolomites and dolomitic limestones. They are conformably overlain by the Ladinian Çağlayık Formation (the Lepen Member of the Radomir Formation of Chatalov 1984) that includes up to 10 m long dolomite and dolomitic limestone olistoliths of the Anisian Bosnek Formation. The olistostromal Çağlayık Formation comprises in general red, brown, ferrous, spotted sandstones with siltstone interbeds. It is conformably overlain by the Upper Ladinian-Lower Carnian Kurudere Formation (the Troyan Formation of Chatalov 1984), which is composed of grey, beige, light grey colour, massive in general, locally

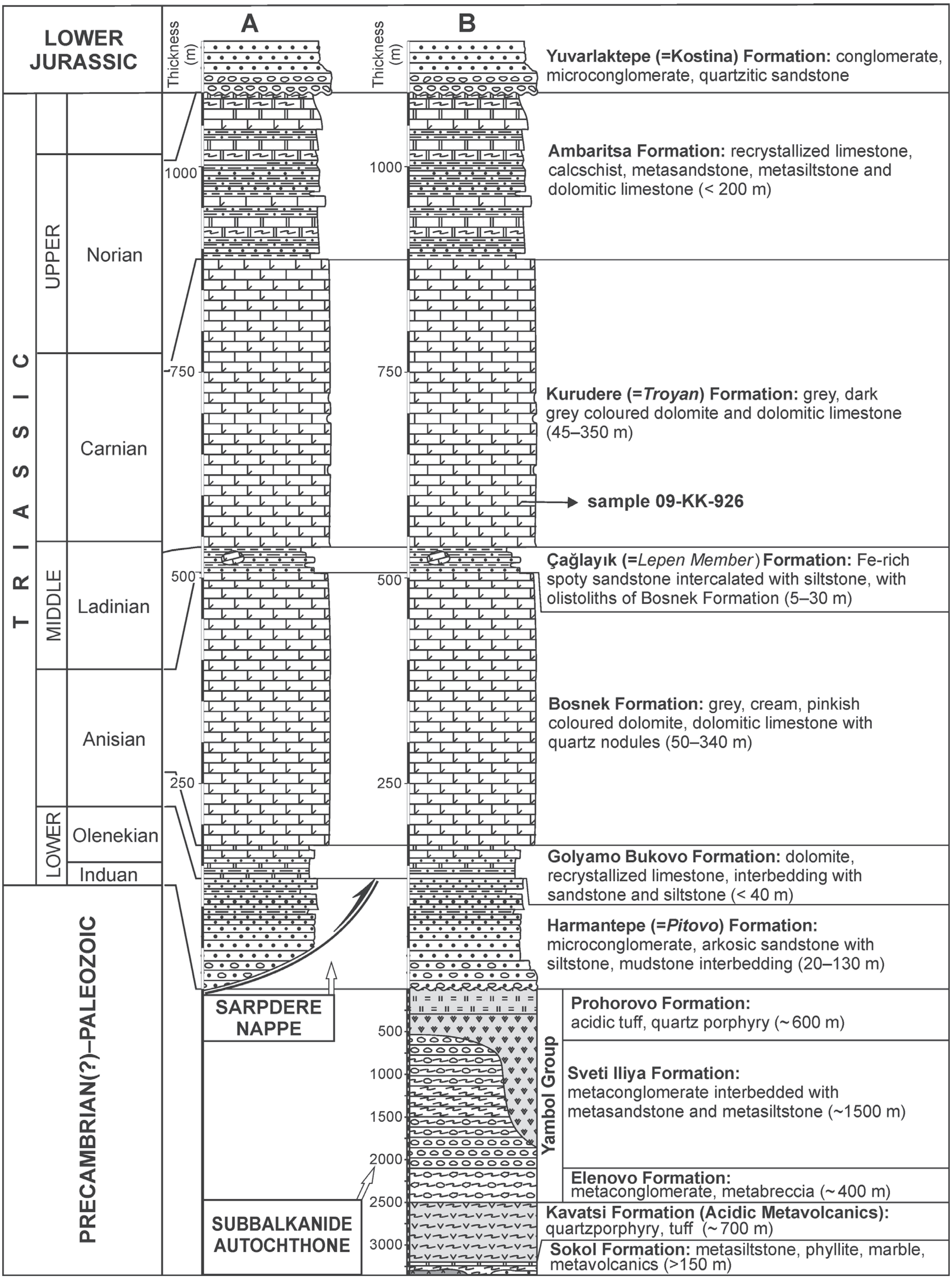

Fig. 5. Generalized stratigraphic columnar sections of (**A**) Sarpdere Nappe and (**B**) Subbalkanide sequence (significantly modified from Chatalov 1980 and Vasilev & Dabovski 2010 by new data from Turkey). Note the differences in the pre-Triassic basement in A and B.

Table 2: Distribution of foraminiferal and radiolarian findings in the study area.

Foraminifera-bearing samples	Sample locality	Unit	Age
10-KK-135 and 10-KK-144	Domuzpınar Hill (NE of Kofçaz village)	Domuzpınartepe Fm	Early Jurassic (Sinemurian–Pliensbachian)
10-KK-166	NE of Kula village	Kapaklı Fm in the Doğanköy Nappe	Anisian–Ladinian
10-KK-775	N of Taştepe village	Taştepe Member of Kocayazı Fm in the Doğanköy Nappe	Early Triassic
10-KK-34 and 10-KK-37	northwest of Byala Voda village in Bulgaria	Yazminski Fm in the Mahyadağ Nappe	Carnian–Norian
09-KK-926	SE of Sarpdere village	Kurudere Fm in the Sarpdere Nappe	Ladinian–early Carnian
Radiolaria-bearing samples	**Sample locality**	**Unit**	**Age**
09-Gec-1	N of Geçitağzı village	Balaban Fm	Early Kimmeridgian
10-KK-363-J	SE of Kula village	Balaban Fm	Early Bathonian
10-KK-363-H	SE of Kula village	Balaban Fm	Late Bajocian–Early Bathonian

thick- to very thick-bedded, rarely thin- to medium- and regularly-bedded dolomites and recrystallized limestones with micritic texture. The age of this formation in the Turkish part is given by the recent finding of a number of well-preserved foraminifers such as *Polarisella* ex gr. *elabugae* (Cherdyntsev) (Fig. 6A.6, Table 2), *Endotriadella wirzi* (Koehn-Zaninetti) (Fig. 6A.8, Table 2), *Turriglommina mesotriasica* (Koehn-Zaninetti) (Fig. 6A.9, Table 2), and *Lamelliconus* cf. *procerus* (Liebus) (sample 09-KK-926; Sarpdere village, at Kırklareli-E19-a4 quadrangle sheet, 41°51′51″ N/27°36′26″ E UTM Coordinates), in the recrystallized limestone levels. The top of the sequence is conformably overlain by the Carnian-Norian Ambaritsa Formation (Chatalov 1984) composed of yellow, grey colour, thin- to medium- and regularly-bedded calcschist, dolomite, dolomitic limestone and recrystallized limestone intercalation. This unit is not observed in the Turkish part.

The Mahyadağ Nappe

According to the original definition of Chatalov (1990) in the Bulgarian part, the Strandja type Triassic forms a distinct nappe (the Zabernovo Nappe of Chatalov 1980) and was emplaced from south to north over a pre-Upper Jurassic autochthonous or para-autochthonous basement (also including Subbalkanide type Triassic), presumably during the Late Jurassic-Early Cretaceous compressional events. According to this author, the succession is in an overturned position; the base of the nappe consists of Upper Triassic followed upwards by Middle Triassic very low-grade metasediments, and the top is occupied by Lower Triassic greenschist facies metasediments with sporadic basic and acidic metavolcanics. Later studies (Nikolov et al. 1996; Maliakov 1997; Boncheva & Chatalov 1998), based on scarce fossil findings (palynomorphs and conodonts data), suggest a Paleozoic age for at least a part of these metasediments.

In the Turkish part, this structural unit is located between the Sakar Nappe and the Sarpdere Nappe. It starts (Fig. 7) with the Devonian?-Permian Armutveren Formation (Table 1, the Zaberska Formation in Chatalov 1985). The Devonian age of this formation is determined on the basis of conodonts from thin levels of recrystallized limestones in the metaclastics around Stoilovo village (Boncheva & Chatalov 1998). The Zaberska Formation (Table 1) is composed of alternating reddish, yellowish, thin-bedded quartzite with interbeds of calcschist, dolomite and recrystallized limestone, together with greenish-brownish colour, thin- to medium-bedded and well-foliated quartzschists. The thickness of recrystallized limestone in the Armutveren Formation varies between 0.5 and 10 m. Upwards, it is followed by the 10 m thick uppermost Permian–lowermost Induan (Okuyucu et al. in review) Tütünlüktepe Formation. It displays discontinuous outcrops in the study area and comprises an alternation of grey, dark grey colour, thin- to medium- and regularly-bedded recrystallized limestone with parts of shells of bivalves in places, and green colour, thin foliated metasiltstone. This unit is observed around Tütünlüktepe Hill only on the road between Dereköy-Çağlayık in the Turkish part of the study area.

Both the uppermost Permian–lowermost Induan Tütünlüktepe and the Devonian–?Permian Armutveren Formations are overlain with angular unconformity by the 250 m thick, low-grade metamorphic Çukurpınar Formation (Table 1, the Struvnitsa Formation in Chatalov 1985) of Induan age. It is composed of metasiltstone, metaconglomerate with quartzschist interbeds, metamicroconglomerate and coarse-grained metasandstone. This Triassic unit has been considered a member of the Paleozoic Zaberska Formation by Vasilev & Dabovski (2010) in the Bulgarian part. Nikolov et al. (1996), on the other hand, claimed that the unit corresponds to the Triassic but does not provide any fossil data. The pebbles in the Çukurpınar Formation are polygenetic in character; they are fine to coarse in size and consist of mainly quartz and schist pebbles of the Armutveren Formation.

In Bulgaria, this unit is conformably overlain by the Kushliovo Formation (Vasilev 1998), which comprises dark grey slate, metasiltstone and metasandstone, locally interbedded with recrystallized limestone. In this study, however, these metasediments are interpreted as the lower levels of the Olenekian–Anisian Adatepe Formation (Table 1, the Gramatikovo Formation in Chatalov 1985). This Lower Triassic carbonate-siliciclastic intercalation is overlain by grey, dark grey colour, very thin- to thin-bedded recrystallized limestone and dolomite alternating with metasiltstone interbeds, corresponding to the upper levels of the Adatepe Formation. Upwards, the unit conformably passes into the Anisian–Ladinian Tolpan Formation (Vasilev 2001), which is composed of grey, brownish colour, thin- to medium-bedded phyllite, calcschist and grey, dark grey colour, thin- to medium-bedded recrystallized

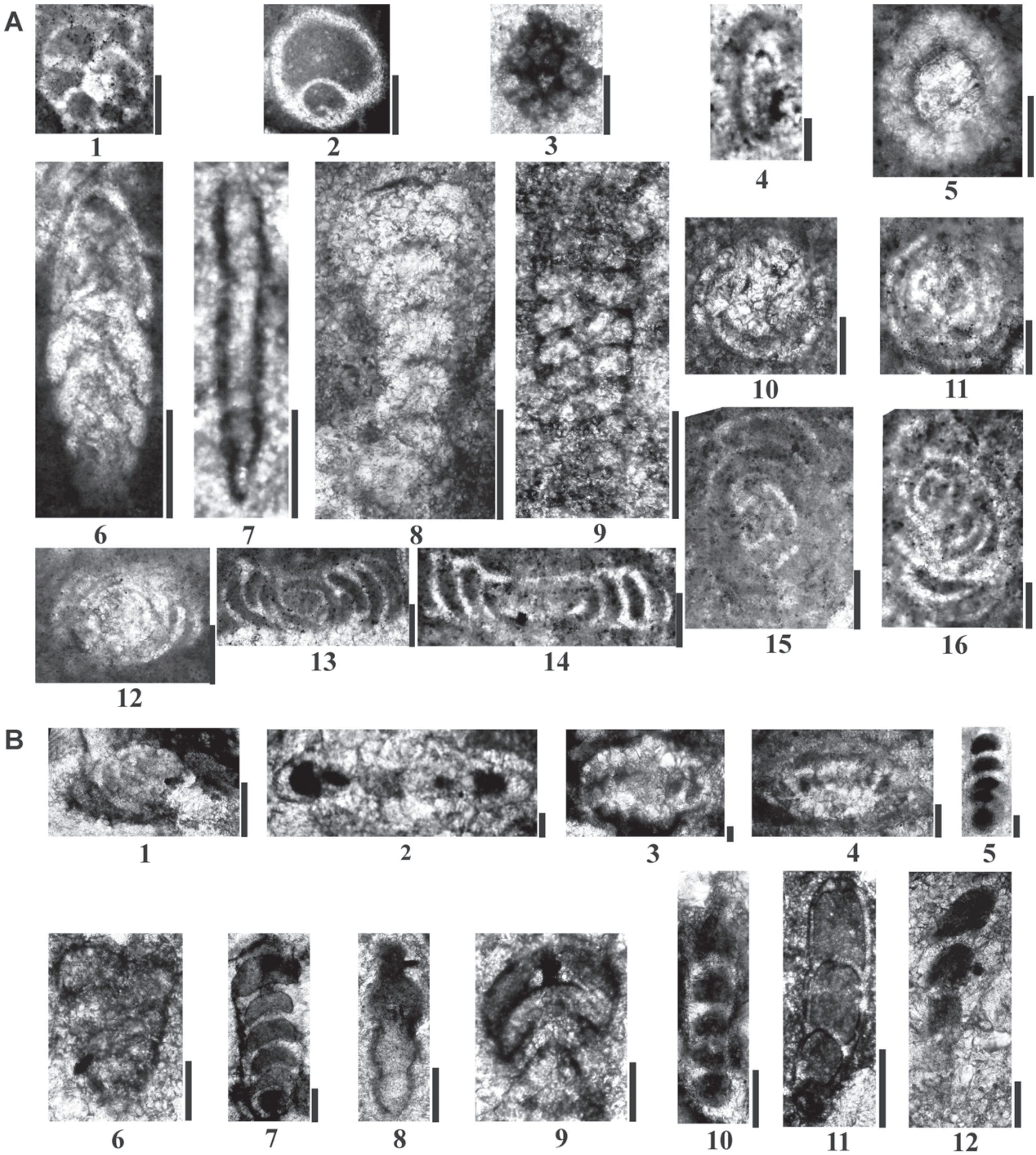

Fig. 6A. Triassic Foraminifera and Dinoflagellata of the Istranca Crystalline Complex from Bulgaria and Turkey. **1** — *Schmidita* cf. *inflata* Fuchs, 1967; sample 10-KK-166, Kapaklı Formation, Turkey. **2** — *Pseudonodosaria obconica* (Reuss, 1868); sample 10-KK-37, Yazminski Formation, Bulgaria. **3** — *Meandrospira cheni* (Ho, 1959); sample 10-KK-775, Kocayazı Formation, Tastepe Member, Turkey. **4** — *Agathammina* cf. *austroalpina* Kristan-Tollmann & Tollman, 1963; sample 10-KK-34, Yazminski Formation, Bulgaria. **5** — *Schizosphaerella* sp. (calcareous dinoflagellate cyst); sample 10-KK-34, Yazminski Formation, Bulgaria. **6** — *Polarisella* ex gr. *elabugae* (Cherdyntsev, 1914); sample 09-KK-926, Kurudere Formation, Turkey. **7** — *Earlandia dunningtoni* (Elliott, 1958); sample 10-KK-775, Kocayazı Formation, Taştepe Member, Turkey. **8** — *Endotriadella wirzi* (Koehn-Zaninetti, 1968); sample 09-KK-926, Kurudere Formation, Turkey. **9** — *Turriglommina mesotriasica* (Koehn-Zaninetti, 1969); sample 09-KK-926, Kurudere Formation, Turkey. **10** — *Aulotortus sinuosus* Weynschenk, 1956; sample 10-KK-166, Kapaklı Formation, Turkey. **11–16** — *Aulotortus friedli* (Kristan-Tollmann, 1962); sample 10-KK-166, Kapaklı Formation, Turkey. Scale bars for all figures 100 μm.

Fig. 6B. Lower Jurassic Foraminifera of the Istranca Crystalline Complex from Turkey. **1** — *Trocholina umbo* Frentzen, 1941; sample 10-KK-144, Domuzpınartepe Formation, Turkey. **2, 3** — *Involutina* gr. *liassica* (Jones, 1853); sample 10-KK-144, Domuzpınartepe Formation, Turkey.

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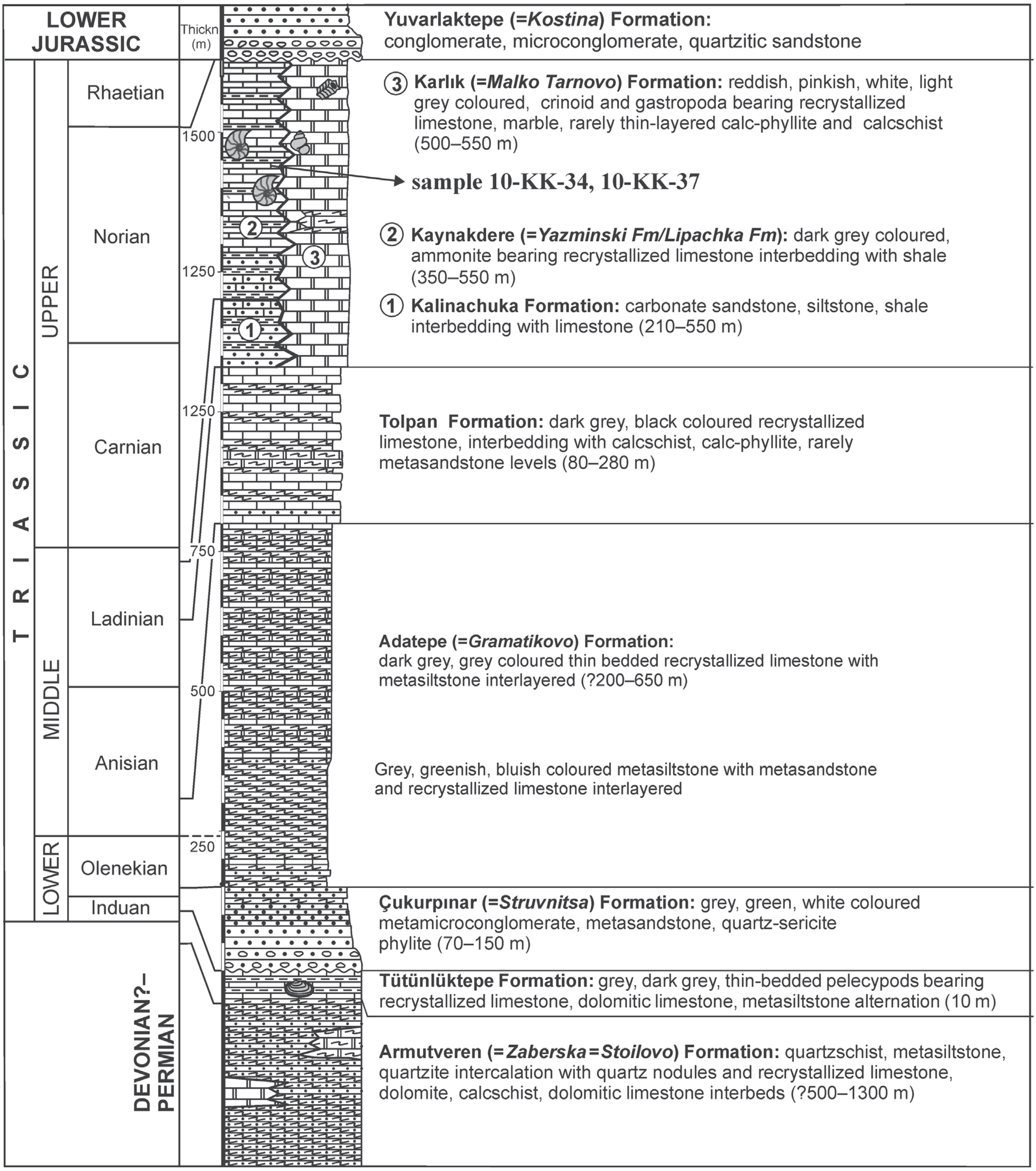

Fig. 7. Generalized stratigraphic columnar section of the Mahyadağ (Istranca type Triassic, Chatalov 1980) Nappe (significantly modified from Chatalov 1980; Vasilev & Dabovski 2010 by new data from Turkey).

Fig. 6B. *Continued:* **4** — *Semiinvoluta clari* Kristan, 1957; sample 10-KK-144, Domuzpınartepe Formation, Turkey. **5** — *Ichthyolaria sacculus* (Terquem, 1866); sample 10-KK-144, Domuzpınartepe Formation, Turkey. **6** — *Verneuilinoides mauritii* (Terquem, 1866); sample 10-KK-144, Domuzpınartepe Formation, Turkey. **7** — *Geinitzinita pupoides* (Bornemann, 1854); sample 10-KK-144, Domuzpınartepe Formation, Turkey. **8** — *Pseudonodosaria tenuis* (Bornemann, 1854); sample 10-KK-144, Domuzpınartepe Formation, Turkey. **9** — *Ichthyolaria* cf. *brizaeformis* (Bornemann, 1854); sample 10-KK-144, Domuzpınartepe Formation, Turkey. **10** — *Nodosaria simoniana* d'Orbigny, 1850; sample 10-KK-144, Domuzpınartepe Formation, Turkey. **11** — *Dentalina* cf. *mauritii* Terquem, 1866; sample 10-KK-144, Domuzpınartepe Formation, Turkey. **12** — *Dentalina subsiliqua* Franke, 1936; sample 10-KK-144, Domuzpınartepe Formation, Turkey.

limestones. In the Bulgarian part, this unit is overlain by the 210–550 m thick Ladinian Kalinachuka Formation (Vasilev 2001), which is composed of an intercalation of carbonaceous sandstone, siltstone and shale with limestone interbeds. This unit has not yet been observed in Turkey. In the Bulgarian part, the Kalinachuka Formation is conformably overlain by grey, dark grey colour, thin- to medium- and regularly-bedded, Upper Ladinian–Norian Kaynakdere Formation (Table 1, the Yazminski Formation in Vasilev 2001) comprising ammonite-bearing recrystallized limestones, rich in foraminifers *Agathammina* cf. *austroalpina* Kristan-Tollmann & Tollman (Fig. 6A.4, Table 2), *Polarisella* ex gr. *hoae* (Trifonova), *Pseudonodosaria obconica* (Reuss) (Fig. 6A.2, Table 2), *Dentalina* sp. and *Trocholina* sp. (sample 10-KK-34; Malko Tarnovo-Burgas road (north-west of Byala Voda village in Bulgaria), 42°10′57″ N/27°28′03″ E UTM Coordinates, sample 10-KK-37; Malko Tarnovo-Zvezdets road (north-west of Byala Voda village in Bulgaria), 42°13′14″ N/27°25′37″ E UTM Coordinates) and *Schizosphaerella* sp. (calcareous dinoflagellate cysts, Fig. 6A.5, Table 2) in the Bulgarian part of the formation. The limestone is locally thin-bedded with laminated shale interbeds. This unit also crops out 1 km north-east of Kula village in the Turkish part. It is overlain by the Upper Ladinian–Norian Karlık Formation (Table 1, the Malko Tarnovo Formation in Chatalov 1983, 1985) which laterally passes into the Kalinachuka and Kaynakdere Formations. The Karlık Formation covers large areas in the study area. It was considered to be of Jurassic age by Çağlayan & Yurtsever (1998) and included in their Kapaklı Formation. The formation comprises reddish, pinkish, locally grey and white colour, laminated, thick- to very thick-bedded recrystallized limestones and marbles with saccaroid texture. In general it is massive, however, regular local bedding can be observed in the unit. Within the marbles, 1–4 m thick, green, yellowish-green colour, medium- to thick-bedded schist and yellow, light brown calcschist interbeds can also be observed. The recrystallized limestones and marbles can locally include crinoid fossils as for instance in the east of Çağlayan and north of Çukurpınar villages (Fig. 3). The Karlık Formation (Çağlayan & Yurtsever 1998) is the uppermost unit of the Mahyadağ Nappe under Jurassic cover. It has been thrust during post-Campanian time upon the Santonian–Campanian granitoids of the Dereköy-Demirköy pluton (Table 1, the Malko Tarnovo pluton) and has caused local mylonitic deformation, as seen to the north-east of Kula village.

The Doğanköy Nappe

The Doğanköy Nappe is the uppermost structural unit of the CIN and consists of a Precambrian–Lower Paleozoic basement and its Triassic cover. In Bulgaria, however, Chatalov (1980) regards it as autochthonous and includes the Triassic rocks in his Sakar type Triassic. Gocev (1985) and Dabovski et al. (1990) on the other hand consider this structural unit to be allochthonous and place it between their autochthonous (?) Subbalkanide (the Sarpdere Nappe) and the Zabernovo Unit (Strandja type Triassic) as an intermediate nappe. While the Precambrian–Lower Paleozoic basement rocks together with the lower part of the Lower Triassic (Induan–Lower Olenekian) cover units have undergone amphibolite facies metamorphism, the upper part of the Lower Triassic (Upper Olenekian) and the Middle Triassic rock units were affected by greenschist facies metamorphism together with Sarpdere and Istranca nappes during Dogger–Early Cretaceous. The Precambrian and the Lower Triassic rock units of the Doğanköy Nappe were retrograded during this metamorphic event.

The Doğanköy Nappe comprises the Tekedere Group (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006) including Precambrian–Lower Paleozoic gneisses, schists, amphibolites, calcschists, quartzites, etc. (Fig. 8). The rocks of the Tekedere Group are locally affected by partial melting to produce migmatites with compositionally and texturally different leucosomes. In these basement rock units, gabbroic, granodioritic and granitic intrusions have also undergone amphibolite facies metamorphism. These mafic and felsic intrusions may correspond to the Carboniferous orthogneisses of Natal'in (2006) and the leucocratic gneisses of Sunal et al. (2006). They have generated a garnet-rich contact-metamorphic aureole at the contact to the metasedimentary host-rocks of the Tekedere Group.

The metasediments of the Tekedere Group and the Upper Carboniferous–Lower Permian intrusive rocks are cut by the granitoids of the Kırklareli Group (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006).

This crystalline basement is unconformably overlain by conglomerates of the Lower Triassic Evciler Formation. The pebbles are composed of polygenetic quartzite, schist, granitic gneiss, amphibolite and elongated pebbles with gneissose texture. The Paleokastro Formation in Bulgaria (Chatalov 1980) and the Caferintaşları Metaconglomerate described by Çağlayan & Yurtsever (1998) and Okay & Yurtsever (2006) in Turkey are not distinct metaconglomerate levels, but correspond to the Evciler Formation. The Lower Triassic Şermat Quartzite, Rampana Quartzite and Çiftlik Quartzite around Kızılagaç were interpreted as having lateral and vertical transitions to the Evciler Gneiss (Çağlayan & Yurtsever 1998), but they do not have direct stratigraphical relations based on the new field observations. Hence, they are parts of a completely different tectono-stratigraphic unit and have to be excluded from the units of the Istranca Crystalline Complex. The metaconglomerates of the Evciler Formation are overlain by another Lower Triassic unit; namely the Induan–Olenekian Fatmakaya Formation with local metaconglomeratic levels.

The Fatmakaya metaclastics are covered conformably by the Lower Triassic (Olenekian) Kocayazı Formation (Table 1, the Ustrem Formation in Chatalov 1985). This formation is the equivalent of the Mahya Schists of Çağlayan & Yurtsever (1998) in the Turkish Istranca and includes the Yenice, the Kanlıdere, the Sepetdere, the Kayınpınardere, the Terzidere, the Taştepe and the Burcanıktepe Members. It starts with the Yenice Member (Çağlayan & Yurtsever 1998) at the bottom, which is composed of quartzite, calcschist, garnet-staurolite-biotite-bearing amphibole schist with marble intercalations. The 25–200 m thick Kanlıdere Member (Table 1, the Mramor Member of the Ustrem Formation in Chatalov 1985) comprises grey, pink, white, bluish colour and thick- to very thick-layered to massive recrystallized limestones and marble. It laterally and vertically passes into the underlying Yenice

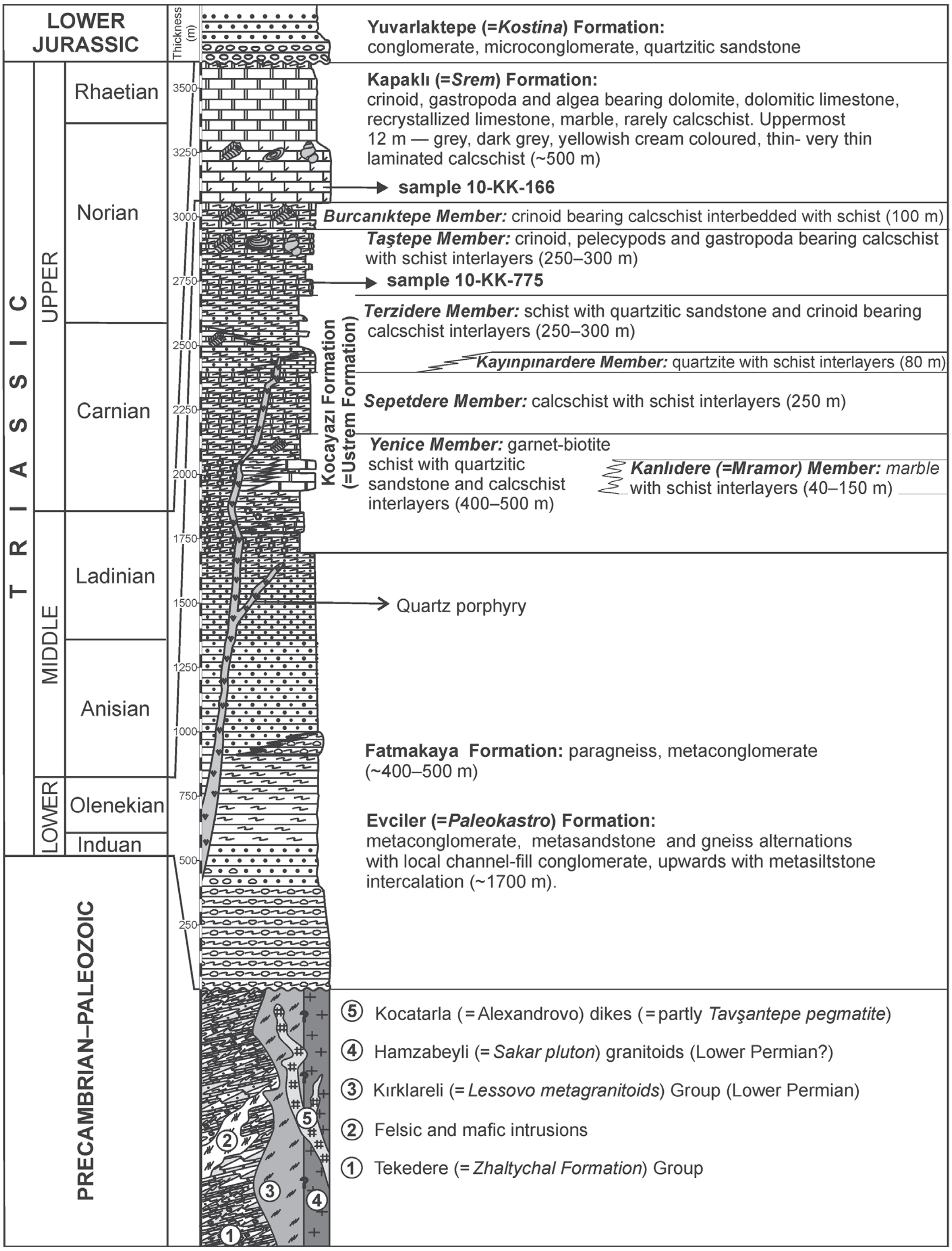

Fig. 8. Generalized stratigraphic columnar section of the Doğanköy Nappe (significantly modified from Chatalov 1980 and Vasilev & Dabovski 2010 by new data from Turkey).

Member. Locally it includes schist interbeds. The conformably overlying Sepetdere Member also laterally passes to the Yenice Member. It consists of 250 m thick calcschists with slate interbeds. The following Kayınpınardere Member comprises medium- to coarse-grained, approximately 80 m thick, yellowish, brownish colour, thin- to medium- and regularly-bedded quartzites and schists with calcschist interbeds. The sequence includes, towards the top, the 250–300 m thick Terzidere Member (Çağlayan & Yurtsever 1998) which is composed of pelitic schists with local crinoid-bearing calcschist interbeds and the approximately 250–300 m thick Taştepe Member (Çağlayan & Yurtsever 1998) comprising thin- to medium-bedded calcschists with crinoids, gastropods and bivalves at the top. Early Triassic foraminifers, such as *Meandrospira cheni* (Ho) (Fig. 6A.3, Table 2), *Earlandia dunningtoni* (Elliot) (Fig. 6A.7, Table 2), *Polarisella* ex gr. *hoae* (Trifonova), *Hoyenella* gr. *sinensis* (Ho), *Spiroplectammina* aff. *dobrudzhiana* Trifonova, *Ammodiscus* sp. as well as the annelid species *Spirorbis phlyctaena* Brönnimann & Zaninetti (sample 10-KK-775, at Taştepe village, at Kırklareli-E18-a2 quadrangle sheet, 41°58′27″ N/27°08′15″ E UTM Coordinates) were determined from this member in the Turkish part. The overlying Burcanıktepe Member, approximately 100 m thick, is composed of calcschists and interbedded metapelitic rocks with abundant crinoids (Table 1, the Kerimarski Member of Ustrem Formation in Chatalov 1985). The rocks of the Kocayazı Formation are frequently intruded by pegmatite, quartz veins and quartz porphyry dykes of probable end-Triassic magmatism.

Çağlayan & Yurtsever (1998) assigned a Liassic age to the crinoidal calcschists of the Burcanıktepe Member (the Çukurpınar Calcschist Member of Çağlayan & Yurtsever 1998) with the help of crinoids. In a recent study (Hagdorn & Göncüoğlu 2007) the same rocks were dated by the presence of the genus *Holocrinus,* a crinoid clade that occurs worldwide in Lower and Middle Triassic sediments. The uppermost unit of the Doğanköy Nappe is the Anisian-Ladinian Kapaklı Formation (Table 1, the Srem Formation in Chatalov 1985) which is composed, from bottom to top, of dolomite, dolomitic limestone, recrystallized limestone, marble and up to 20 m thick calcschists. The dolomites and the dolomitic limestones observed at the basement of the Kapaklı Formation are grey, light grey in colour, thick- to very thick-bedded and locally massive. They include abundant crinoids, gastropods and some undeterminable algae. The overlying recrystallized limestone and marbles are bluish, pinkish, whitish in colour and massive in general and locally thick- to very thick-bedded. The recrystallized limestone levels from the Turkish part include the *Schmidita* cf. *inflata* Fuchs (Fig. 6A.1, Table 2), *Aulotortus sinuosus* Weynschenk (Fig. 6A.10, Table 2), *Aulotortus friedli* (Kristan-Tollmann) (Fig. 6A.11–16, Table 2), *Trochammina almtalensis* Koehn-Zaninetti, and *Nodosaria* sp. (sample10-KK-166, north-east of Kula village, at Kırklareli-D18-c4 quadrangle sheet, 42°00′45″ N/27°18′16″ E UTM Coordinates) foraminiferal association which indicates Middle–?Late Triassic age. The calcschists that are located at the top of the formation are grey, whitish in colour and thin- to medium-bedded. The Kapaklı Formation, which is determined as Jurassic by Çağlayan & Yurtsever (1998) and Triassic–?Liassic by Okay & Yurtsever (2006) is actually of Middle Triassic age. Our new crinoid finding (H. Hagdorn, written communication, 2010) from the dolomitic lower part suggests an Anisian–Ladinian age, which is in accordance with Chatalov (1985)'s data from Bulgaria.

According to data from Turkish Istranca, the earliest common overstep sequence of rock units of the Doğanköy, the Mahyadağ and the Sarpdere Nappes is the Yuvarlaktepe Formation (Table 1, the Kostina Formation in Sapunov et al. 1997) of Early Jurassic age. It overlies the older units and their primary tectonic contacts with an angular unconformity (Fig. 9A,B). However, the following compressional events resulted in re-arrangement of the structural units, where slices of the Doğanköy Nappe are observed above the Jurassic cover sequences (e.g. Fig. 9C).

Such an observation in Bulgaria led Gerdjikov et al. (2005a) to attribute the Sakar Nappe in Bulgaria to the Rhodope terrane.

Jurassic cover of the Cimmerian Istranca Nappes (CIN) and their radiolarian assemblages

The Jurassic sequence sealing the first nappe movements during the pre-Liassic and representing the common cover of the CIN starts with the Early Jurassic Yuvarlaktepe Formation (Table 1, Kostina Formation in Sapunov et al. 1967; Sapunov 1999). It comprises red, yellowish, brownish, massive, and locally thick- to very thick-bedded conglomerates, microconglomerates and coarse-grained sandstones (Fig. 10). Pebbles of the conglomerate are composed mainly of quartz but also include pebbles of the older units. This unit is overlain by the Lower Jurassic Domuzpınartepe Formation (Table 1, the Ozirovo Formation in Sapunov et al. 1967; Sapunov 1999) which is composed of grey, white in general massive and locally thick- to very thick-bedded dolomite, dolomitic limestone and recrystallized limestone with belemnites, locally abundant crinoids, abundant and large pelecypod and gastropod fossils. The foraminiferal assemblage *Trocholina umbo* Frentzen (Fig. 6B.1, Table 2), *Involutina* gr. *liassica* (Jones) (Fig. 6B.2–3, Table 2), *Semiinvoluta clari* Kristan (Fig. 6B.4, Table 2), *Ichthyolaria sacculus* (Terquem) (Fig. 6B.5, Table 2), *Verneuilinoides mauritii* (Terquem) (Fig. 6B.6, Table 2), *Geinitzinita pupoides* (Bornemann) (Fig. 6B.7, Table 2), *Pseudonodosaria tenuis* (Bornemann) (Fig. 6B.8, Table 2), *Ichthyolaria* cf. *brizaeformis* (Bornemann) (Fig. 6B.9, Table 2), *Nodosaria simo-*

Fig. 9. Geological cross-sections in the study area. **A** — Field photos showing the contact relationships between the Kapaklı Formation of Doğanköy Nappe and overlying Jurassic cover units in the Yuvarlaktepe section, 2.5 km S of Kula village, Turkey (at Kırklareli-E18-b1 quadrangle sheet, 41°58′54″ N/27°18'58″ E UTM Coordinates). **B** — The contact relation between Jurassic cover rock units on the Ambaritsa Formation of the Sarpdere Nappe in the Zvezdets section, 1 km W of Zvezdets village, Bulgaria (between the UTM Coordinates: starting at 42°06′20″ N/27°24'05″ E; finishing at 42°06′44″ N/27°25′04″ E). **C** — The Çağlayık section showing the nappe and thrust structures in Çağlayık village, Turkey (at Kırklareli-D18-c4 quadrangle sheet, between the UTM coordinates: starting at 42°02′00″ N/27°19′42″ E; finishing at 42°01′12″ N/27°21′51″ E). **D** — The Kurudere section showing the imbricated structures in the SE Sarpdere village, Turkey (at Kırklareli-E19-a4 quadrangle sheet, between the UTM coordinates: starting at; 41°51′25″ N/27°35′35″ E; finishing at 41°51′28″ N/27°36′32″ E). **E** — Figure showing the highly tectonized unit of the Üsküp-Çukurpınar section between Üsküp and Çukurpınar village (at Kırklareli-E18-b3 quadrangle sheet, between the UTM Coordinates: starting at 41°44′35″ N/27°24′30″ E; finishing at 41°50′20″ N/27°28′00″ E).

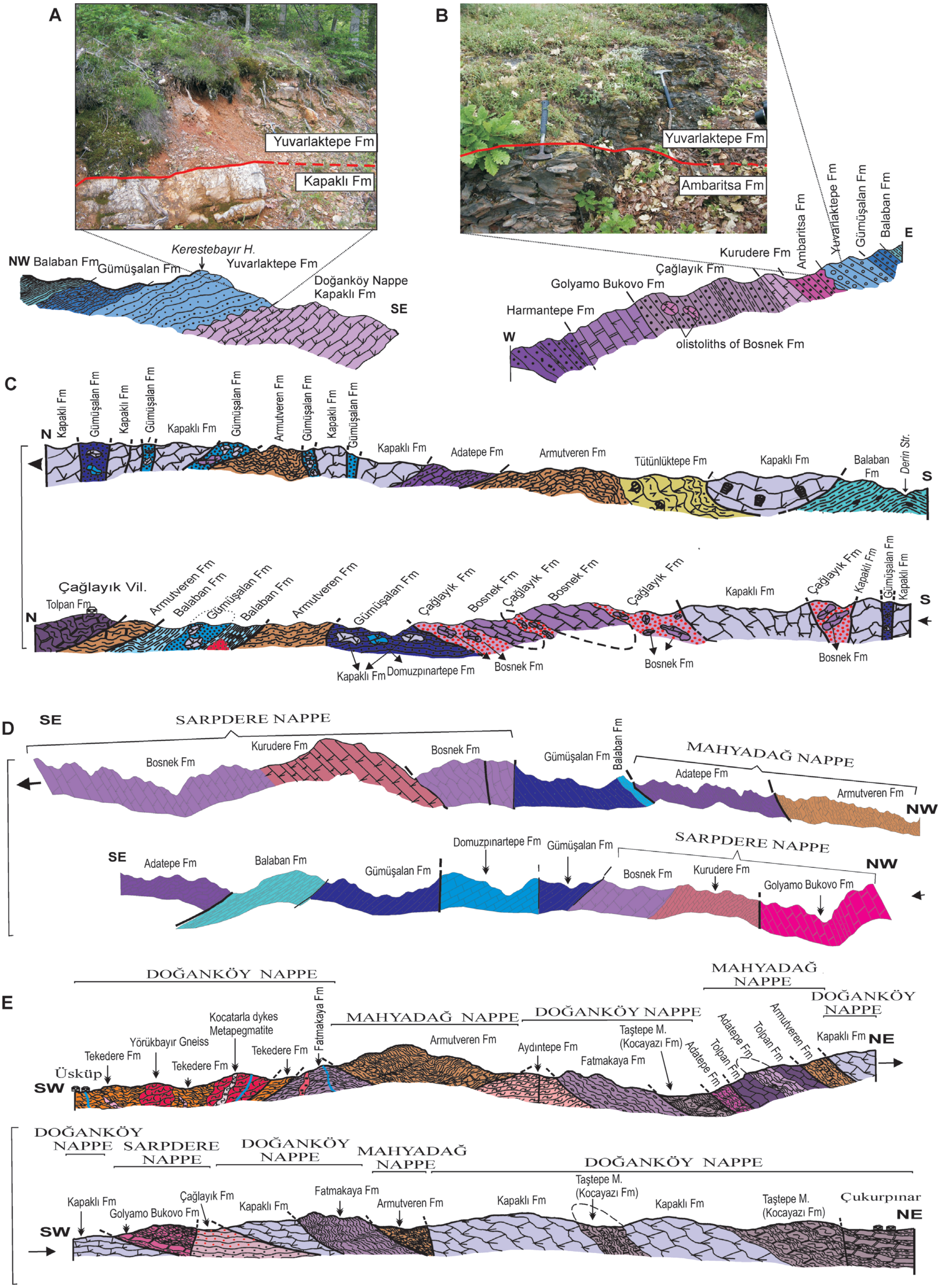
A
Yuvarlaktepe Fm
Kapaklı Fm
NW Balaban Fm
Gümüşalan Fm
Kerestebayır H.
Yuvarlaktepe Fm
Doğanköy Nappe
Kapaklı Fm
SE
B
Yuvarlaktepe Fm
Ambaritsa Fm
Kurudere Fm
Ambaritsa Fm
Yuvarlaktepe Fm
Gümüşalan Fm
Balaban Fm
E
Çağlayık Fm
Golyamo Bukovo Fm
Harmantepe Fm
W
olistoliths of Bosnek Fm
C
N
Kapaklı Fm
Gümüşalan Fm
Adatepe Fm
Armutveren Fm
Tütünlüktepe Fm
Balaban Fm
Derin Str.
S
Çağlayık Vil.
Tolpan Fm
Çağlayık Fm
Bosnek Fm
Domuzpınartepe Fm
D
SE
SARPDERE NAPPE
Kurudere Fm
MAHYADAĞ NAPPE
NW
Golyamo Bukovo Fm
E
DOĞANKÖY NAPPE
Kocatarla dykes
Metapegmatite
Yörükbayır Gneiss
Tekedere Fm
Fatmakaya Fm
Üsküp
SW
Aydıntepe Fm
Taştepe M.
(Kocayazı Fm)
NE
Çukurpınar

Fig. 9.

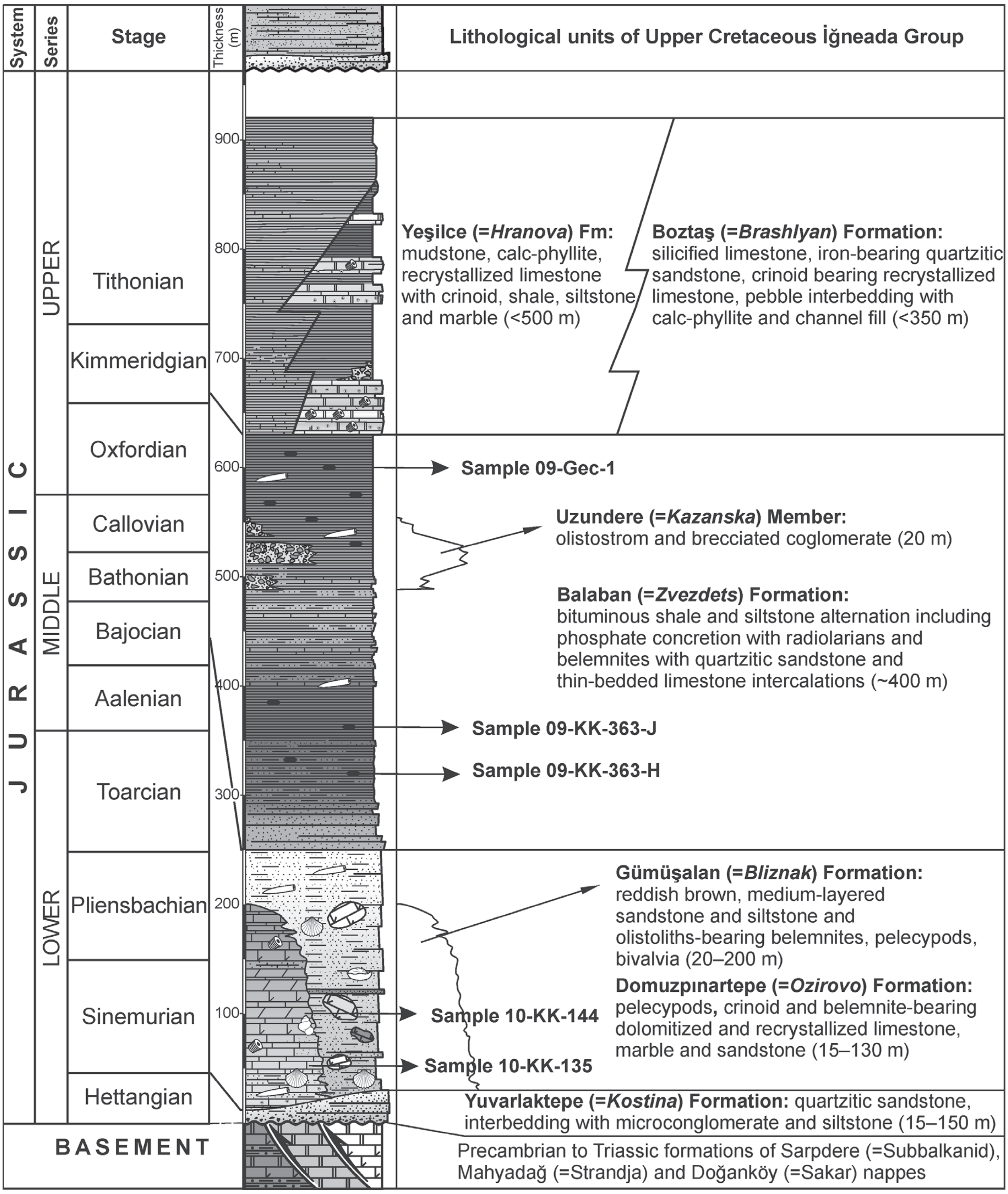

Fig. 10. Stratigraphic section of the Jurassic rock units (significantly modified from Chatalov 1985; Sapunov 1999; Vasilev & Dabovski 2010 by new data from Turkey).

niana d'Orbigny (Fig. 6B.10, Table 2), *Dentalina* cf. *mauritii* Terquem (Fig. 6B.11, Table 2), *Dentalina* cf. *subsiliqua* Franke (Fig. 6B.12, Table 2), *Ophthalmidium liasicum* (Kuebler & Zwingli), and *Cornuspira* sp. is determined in samples 10-KK-135, 10-KK-144 from Domuzpınar Hill at 2.5 km north-east of the Kofçaz village (at Kırklareli-E18-a2 quadrangle sheet, 27°11′13″ N/41°58′10″ E UTM Coordinates; Fig. 3) and indicate an Early Jurassic (Sinemurian–Pliensbachian) age.

The unit laterally and vertically passes to the Sinemurian-Lower Bajocian Gümüşalan Formation (Table 1, the Bliznak Formation in Chatalov 1985), which is an alternation of sandstone and siltstone. The Gümüşalan Formation is olistostromal in character and includes dolomitic and dolomitic limestone olistoliths from various units, including the Kapaklı, the Karlık, and the Bosnek Formations of the CIN as well as the underlying Domuzpınartepe Formation. The sandstones of the formation are thin- to medium-bedded and yellow, brown and red in colour. Locally this sandstone includes abundant macrofossils such as bivalves (*Pseudopecten*) and belemnites. The siltstones intercalated with sandstones are yellowish, greenish, brownish in colour, thin-bedded and laminated. The extensively folded formation passes into the Balaban Formation (Table 1, the Zvezdets Formation in Chatalov 1985). A 42 m thick unit begins at the base with brown — light brown and yellowish, medium- to thick- and regularly-bedded quartzitic sandstones. It passes into black, dark grey, thin- to very thin-bedded and laminated bituminous shale and yellowish-greenish colour, thin-bedded, laminated siltstones towards the upper part. It typically includes black shale intervals with large (up to 4 cm) idiomorphic pyrite and chalcopyrite crystals. At the top of the formation these shales include phosphate concretions which are 2–80 cm in diameter. Three spot samples from these phosphate concretions from the Balaban Formation have yielded radiolarian assemblages. Two of them (09-KK-363-H and 09-KK-363-J) collected from the concretions in bituminous shale near Kula village (at Kırklareli-D18-c4 quadrangle sheet, 42°00′02″ N, 27°17′45″ E and at Kırklareli-E18-b1 quadrangle sheet, 41°59′41″ N/27°17′57″ E UTM Coordinates, Fig. 3, Table 2) yielded diverse but moderately-preserved radiolarians. The radiolarian fauna of sample 09-KK-363-H contains the following taxa: *Pantanellium* sp. (Fig. 11.3), *Triactoma* spp., *Xiphostylus* spp. (Fig. 11.4,5), *Homoeparonaella argolidensis* Baumgartner (Fig. 11.24), *Hexasaturnalis suboblongus* (Yao) (Fig. 12.8), *Bernoullius rectispinus delnortensis* Pessagno, Blome & Hull (Fig. 12.11), *Bernoullius rectispinus leporinus* Conti & Marcucci (Fig. 12.13), *Hsuum* spp. (Fig. 12.21) and *Transhsuum* sp. (Fig. 12.22). Due to co-occurrence of two characteristic taxa (*Homoeparonaella argolidensis* and *Hexasaturnalis suboblongus* (Yao), the age of sample 09-KK-363-H is assigned as Late Bajocian–Early Bathonian corresponding to UA 4-5 (Baumgartner et al. 1995; Dumitrică & Dumitrică-Jud 2005; Chiari et al. 2012; Fig. 13).

The radiolarian assemblage from sample 09-KK-363-J comprises *Gorgansium* sp. aff. *G. silviense* Pessagno & Blome (Fig. 11.1), *Gorgansium* sp. (Fig. 11.2), *Triactoma jonesi* (Pessagno) (Fig. 11.6,7), *Xiphostylus* sp., *Angulobracchia purisimaensis* (Pessagno) (Fig. 11.9,10), *Emiluvia premyogii* Baumgartner (Fig. 11.16), *Emiluvia* spp., *Higumastra gratiosa* Baumgartner (Fig. 11.21), *H.* sp. cf. *H. gratiosa* Baumgartner (Fig. 11.22), *H.* sp. cf. *H. inflata* Baumgartner (Fig. 11.23), *Homoeparonaella argolidensis* Baumgartner (Fig. 11.24), *Homoeparonaella elegans* (Pessagno) (Fig. 12.1), *Tetraditryma praeplana* Baumgartner (Fig. 12.2), *Tetratrabs* sp. (Fig.12.3), *Tritrabs simplex* Kito & De Wever (Fig. 12.4), *Hexasaturnalis nakasekoi* Dumitrică & Dumitrică-Jud (Fig. 12.5–6), *Hexasaturnalis suboblongus* (Yao) (Fig. 12.7), *Spongosaturninus bispinus* (Yao) (Fig. 12.9), *Bernoullius dicera* (Baumgartner) (Fig. 12.10), *B. rectispinus delnortensis* Pessagno, Blome & Hull (Fig. 12.12), *B. rectispinus leporinus* Conti & Marcucci (Fig. 12.14–15), *Perispyridium* sp. cf. *P. gujohachimanense* Takemura (Fig. 12.16), *Perispyridium* sp. (Fig. 12.17), *Parahsuum officerense* (Pessagno & Whalen) (Fig. 12.18), *Hsuum* spp., *Napora* sp., *Canelonus*? sp. (Fig. 12.26), *Stichomitra* (?)*takanoensis* Aita (Fig. 12.27). Considering the ranges of two important taxa (*Hexasaturnalis nakasekoi* and *Hexasaturnalis suboblongus*), an Early Bathonian age is assigned to sample 09-KK-363-J corresponding to UA 5 (Baumgartner et al. 1995; Dumitrică & Dumitrică-Jud 2005; Chiari et al. 2012; Fig. 13).

Another sample from a phosphate concretion (09-Gec-1) in shale near Geçitağzı village (at Kırklareli-E18-b1 quadrangle sheet, 41°57′23" N/27°17′50″ E and 41°57′27″ N/27°17′53″ E UTM Coordinates; Fig. 3, Table 2) yielded a less-diverse and poor to moderately-preserved radiolarian assemblage. The radiolarian assemblage of sample 09-Gec-1 is: *Triactoma* sp. (Fig. 11.8), *Paronaella broennimanni* Pessagno (Fig. 11.11), *Paronaella* spp. (Fig. 12.12–15), *Paronaella* sp. cf. *P. mulleri* Pessagno, *Emiluvia* sp. (Fig. 11.17), *Higumastra devilsgapensis* Pessagno, Blome & Hull (Fig. 11.18–20), *Homoeparonaella argolidensis* Baumgartner (Fig. 11.26–27), *Hsuum mclaughlini* Pessagno & Blome (Fig. 12.19), *Hsuum* sp. cf. *mclaughlini* Pessagno & Blome (Fig. 12.20), *Hsuum* spp. (Fig. 12.23–24), *Archaeodictyomitra* sp. (Fig. 12.25). The presence of *Hsuum mclaughlini* is crucial for dating. Although the range of the *Hsuum mclaughlini* was reported as Late Tithonian by Pessagno et al. (1984), the total range of this taxon was reported as Kimmeridgian to Berriasian in later studies (e.g. Kiessling 1999). Together with the presence of this taxa, we take into consideration the last occurrence of *Paronaella broennimanni*, and assign the age of the 09-Gec-1 as Early Kimmeridgian corresponding to UA10 by Baumgartner et al. (1995 and the age data from the other studies, e.g. Pessagno et al. 1984; Pessagno et al. 1993; Kiessling 1999; Fig. 13).

According to these radiolarian data, the depositional age interval of the Balaban Formation in the Turkish side is Late Bajocian to Early Kimmeridgian. In Bulgaria, a Bajocian age was assigned to the equivalent unit (the Zvezdets Formation) by Chatalov (1985) based on belemnites, bivalves, and gastropods. In the Turkish part of Istranca Çağlayan & Yurtsever (1998) and Okay & Yurtsever (2006) assigned this unit to the Balaban graphitic schists of their Mahya Formation. Belemnite fossils were found in this formation in outcrops at about 1 km to the NE of Bliznak village in Bulgaria, on the Dereköy-Geçitağzı road (at Kırklareli E-18-b1 quadrangle sheet, 41°56′12″ N/27°20′33″ E UTM Coordinates, Fig. 3, Table 2) and in the NW of Kofçaz (at Kırklareli quadrangle sheet, 41°58′00″ N/ 27°09′05″ E UTM Coordinates in Turkey).

The Uzundere Member (Table 1, the Kazanska Member in Chatalov 1985) of the Balaban Formation is composed of a 20 m thick brecciated conglomerate. In bituminous, black shales included in the Balaban Formation, cordierite and andalusite minerals were formed due to contact metamorphism related to the intrusion of the Upper Santonian-Campanian (Moore et al. 1980; Aydın 1982) the Dereköy-Demirköy pluton.

The Jurassic sequence at the top grades laterally and vertically into the Upper Jurassic (middle Kimmeridgian–Tithonian?) Yeşilce Formation (Table 1, the Hranova Formation in Chatalov 1985) comprising an intercalation of mudstone, calcphyllite, recrystallized limestone, shale, siltstone and then to (middle Kimmeridgian–Tithonian?) the Boztaş Formation (Table 1, the Brashlyan Formation in Chatalov 1985), which consists of Fe-rich silicified limestone and sandstone including local conglomeratic channel fills. The limestones included in the Boztaş Formation locally include crinoids. Although the

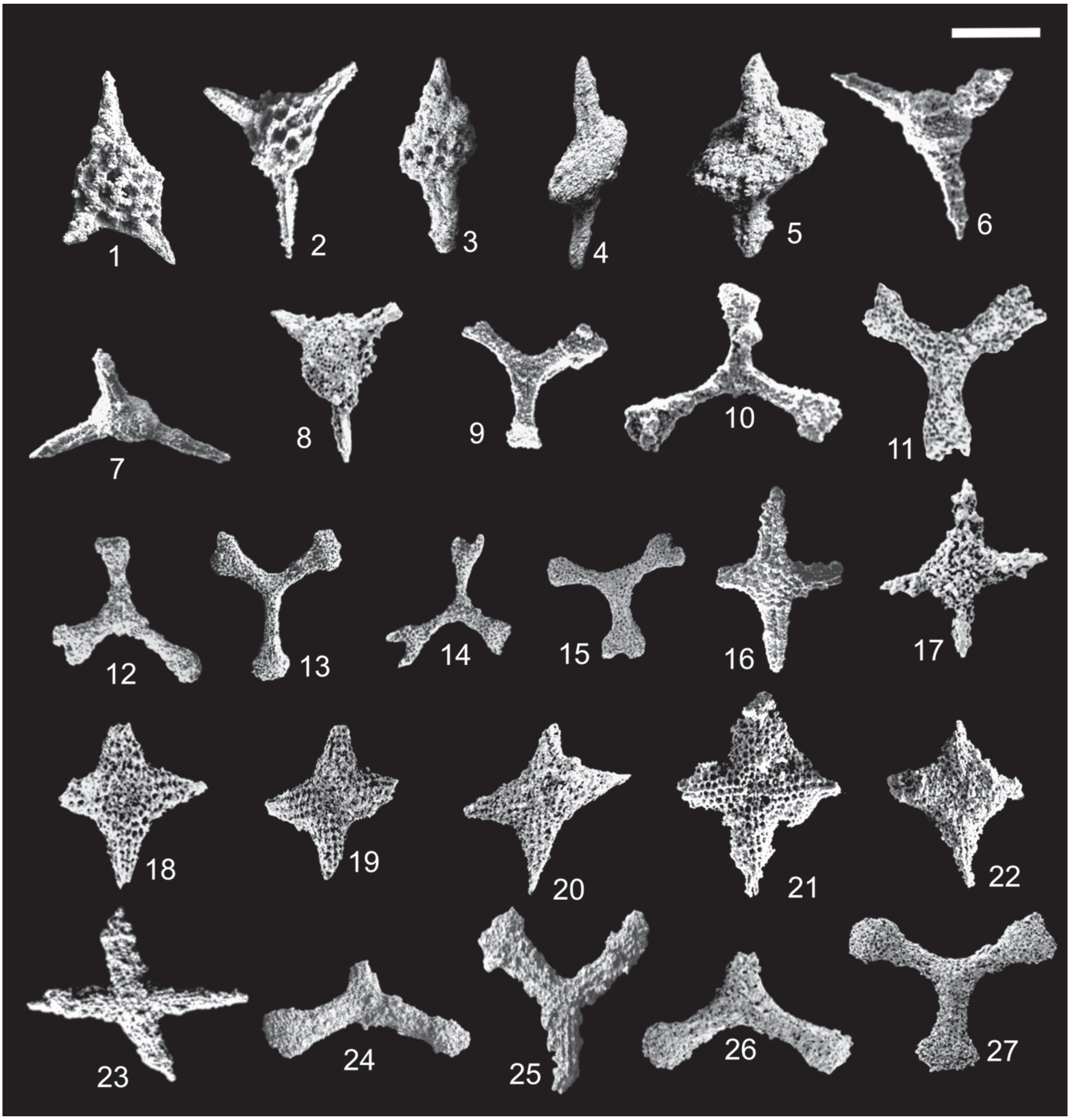

Fig. 11. Scanning electron micrographs of Middle and Late Jurassic radiolarians from the phosphate nodules in black shales of the Balaban Formation. Samples 09-KK-363-H and 09-KK-363-J were taken at Kırklareli-E18-b1 quadrangle sheet (with UTM Coordinates: 46°50′39″ N/05°24′44″ E and 46°49′47″ N/05°25′16″ E; Fig. 2) and sample 09-Gec-1 is from the same lithologies taken from Geçitağzı village (at Kırklareli-E18-b1 quadrangle sheet, with UTM Coordinates: 46°45′14″ N/05°25′09″ E and 46°45′02″ N/05°25′03″ E; Fig. 2). Scale = number of micrometers for each figure. **1** — *Gorgansium* sp. aff. *G. silviense* Pessagno & Blome; 09-KK-363-J, scale bar = 135 μm. **2** — *Gorgansium* sp.; 09-KK-363-J, scale bar = 165 μm. 3 — *Pantanellium* sp.; 09-KK-363-H, scale bar = 130 μm. **4–5** — *Xiphostylus* spp.; both specimens from 09-KK-363-H, scale bar for both specimens = 330 μm. **6–7** — *Triactoma jonesi* (Pessagno); both specimens from 09-KK-363-J, scale bar for both specimens = 300 μm. **8** — *Triactoma* sp.; 09-Gec-1, scale bar = 160 μm. **9–10** — *Angulobracchia purisimaensis* (Pessagno); both specimens from 09-KK-363-J, scale bar = 400 μm. **11** — *Paronaella broennimanni* Pessagno; 09-Gec-1, scale bar = 230 μm. **12–15** — *Paronaella* spp.; all specimens from 09-Gec-1, scale bar for all specimens = 400 μm. **16** — *Emiluvia premyogii* Baumgartner; 09-KK-363-J, scale bar = 270 μm. **17** — *Emiluvia* sp.; 09-Gec-1, scale bar = 160 μm. **18–20** — *Higumastra devilsgapensis* Pessagno, Blome & Hull; all specimens from Gec-1, scale bar for all specimens = 400 μm. **21** — *Higumastra gratiosa* Baumgartner; 09-KK-363-J, scale bar = 300 μm. **22** — *Higumastra* sp. cf. *H. gratiosa* Baumgartner; 09-KK-363-J, scale bar = 400 μm. **23** — *Higumastra* sp. cf. *H. inflata* Baumgartner; 09-KK-363-J, scale bar = 300 μm. **24–27** — *Homoeparonaella argolidensis* Baumgartner. 24 — 09-KK-363-H, 25 — 09-KK-363-J, 26–27 — 09-Gec-1, scale bar for all specimens = 350 μm.

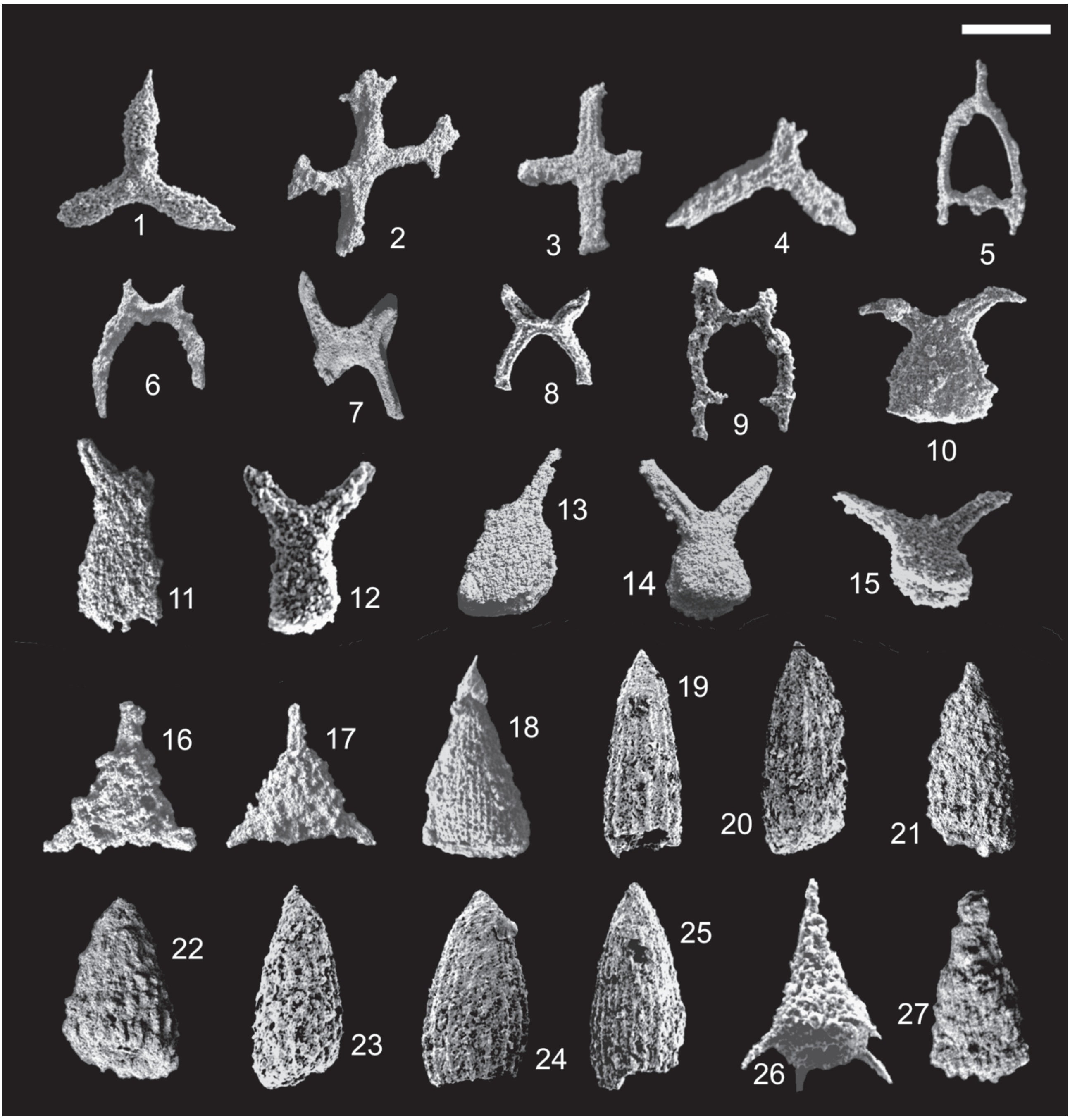

Fig. 12. Scanning electron micrographs of Middle and Late Jurassic radiolarians from the Istranca "Massif". The sample locations are the same as in Fig. 12. Scale = number of micrometers for each figure. **1** — *Homoeparonaella elegans* (Pessagno); 09-KK-363-J, scale bar = 300 μm. **2** — *Tetraditryma praeplana* Baumgartner, 09-KK-363-J, scale bar = 300 μm. **3** — *Tetratrabs* sp.; 09-KK-363-J, scale bar = 250 μm. **4** — *Tritrabs simplex* Kito & De Wever; 09-KK-363-J, scale bar = 200 μm. **5–6** — *Hexasaturnalis nakasekoi* Dumitrică & Dumitrică-Jud; 09-KK-363-J, scale bar = 250 and 200 μm, respectively. **7–8** — *Hexasaturnalis suboblongus* (Yao); 7 — 09-KK-363-J, 8 — 09-KK-363-H, scale bar for both figures = 200 μm. **9** — *Spongosaturninus bispinus* (Yao); 09-KK-363-J, scale bar = 185 μm. **10** — *Bernoullius dicera* (Baumgartner); 09-KK-363-J, scale bar = 360 μm. **11–12** — *Bernoullius rectispinus delnortensis* Pessagno, Blome & Hull; 11 — 09-KK-363-H, 12 — 09-KK-363-J, scale bar for both specimens = 150 μm. **13–15** — *Bernoullius rectispinus leporinus* Conti & Marcucci; 13 — 09-KK-363-H, 14–15 — 09-KK-363-J, scale bar for all specimens = 200 μm; **16** — *Perispyridium* sp. cf. *P. gujohachimanense* Takemura; 09-KK-363-J scale bar = 200 μm. **17** — *Perispyridium* sp.; 09-KK-363-J, scale bar = 200 μm. **18** — *Parahsuum officerense* (Pessagno & Whalen); 09-KK-363-J, scale bar = 100 μm. **19** — *Hsuum mclaughlini* Pessagno & Blome; 09-Gec-1, scale bar = 150 μm. **20** — *Hsuum* sp. cf. *H. mclaughlini* Pessagno & Blome; 09-Gec-1, scale bar = 180 μm. **21, 23–24** — *Hsuum* spp.; 21 — 09-KK-363-H, 23–24 — 09-Gec-1, scale bar for all specimens = 150 μm. **22** — *Transhsuum* sp.; 09-KK-363-H, scale bar = 150 μm. **25** — *Archaeodictyomitra* sp.; 09-Gec-1, scale bar = 150 μm. **26** — *Canelonus*? sp.; 09-KK-363-J, scale bar = 80 μm. **27** — *Stichomitra*(?) *takanoensis* Aita; 09-KK-363-J, scale bar = 125 μm.

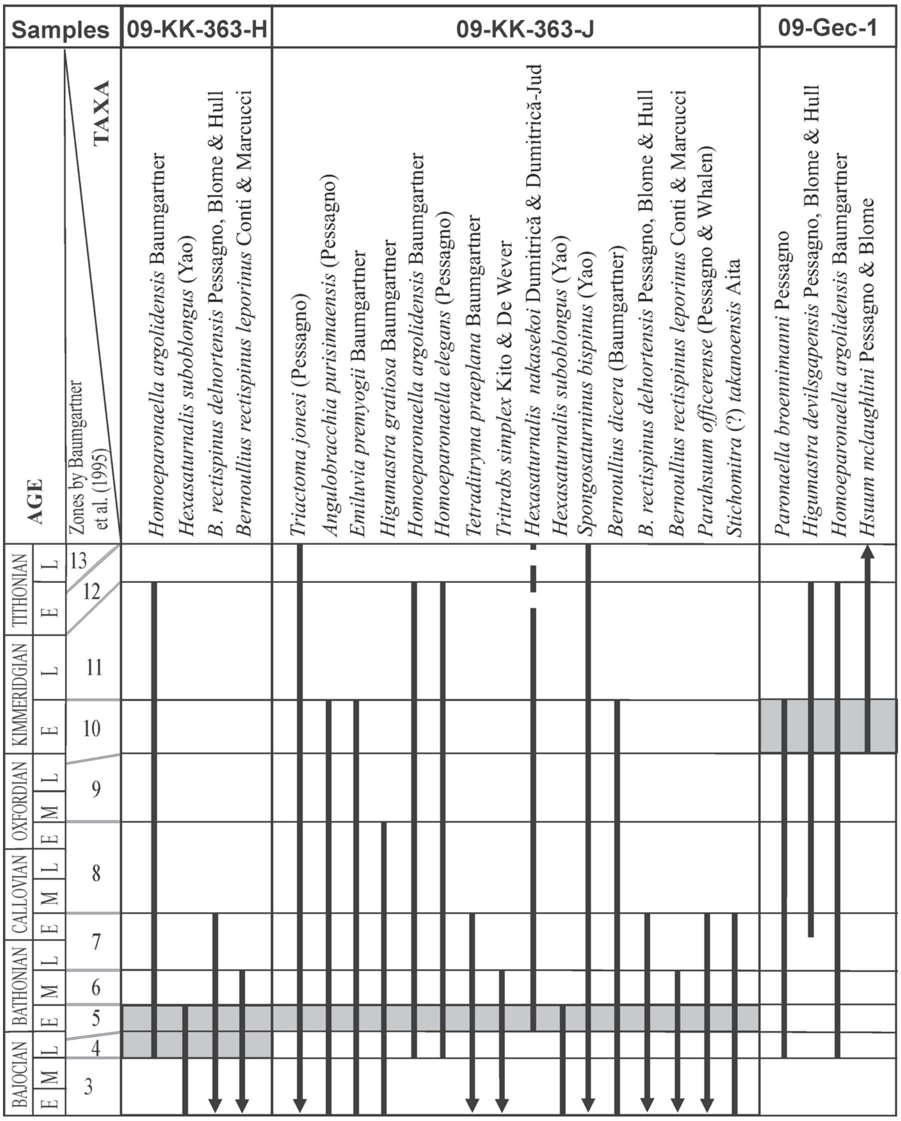

Fig. 13. Stratigraphic ranges of radiolarian taxa obtained from 09-KK-363-H, 09-KK-363-J and 09-Gec-1 from the Balaban Formation of the "Strandja Massif". Grey area shows the determined age of assemblages. Dotted lines show the supposed parts of stratigraphic intervals of taxa.

age of these two formations have been reported as Bathonian by Chatalov (1985) and Sapunov (1999), new radiolarian dating from the underlying Balaban Formation reveals that their depositional ages could be as young as Late Jurassic. Crinoids are abundant in outcrops N of Dereköy on the Turkish-Bulgarian border which can be followed in Bulgaria.

Upper Cretaceous volcano-sedimentary cover

The Sarpdere and the Mahyadağ Nappes, together with their Jurassic cover, are overlain with angular unconformity by rocks of the Cenomanian–Santonian İğneada Group (Çağlayan & Yurtsever 1998), which display characteristics of a volcano-sedimentary succession (Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006). This unit is the stratigraphic equivalent to Varshilo (Petrova et al. 1980), Grudovo (Petrova et al. 1980) and Michurin (Petrova & Simeonov 1988) Groups in Bulgaria. In the CIN, the Jurassic and Cenomanian-Santonian cover units were intruded by the Upper Santonian-Campanian Dereköy-Demirköy pluton, which includes granite, granodiorite, monzonite, syenite, gabbro, monzodiorite as intrusive bodies. The vein rocks observed are diorite porphyry, diabase, pegmatite and aplite.

Evaluation of the new data and discussion

Stratigraphy

The new stratigraphic data obtained in the Turkish Istranca evidence the presence of structural units with different lithostratigraphies, ages and basements. This contrasts with the suggestion of earlier studies (e.g. Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006 and others) who considered a single lithostratigraphic succession all along the "Massif".

To start with the dissimilarities in the pre-Triassic basement of the CIN, the basement of the Subbalkanide Autochthon in Bulgaria is not observed in the Turkish part due to the tectonic activities. Moreover, the low-grade metamorphic succession in this unit exposed north of Topolovgrad is dissimilar to the pre-Triassic basement of the structurally overlying Mahyadağ Nappe, especially in regard to lithostratigraphic and metamorphic properties. The basement rocks of the Mahyadağ and Doğanköy Nappes also do not show any geological continuity. The former one characterizes a Variscan continental margin deposition without the relicts of the Late Carboniferous–Early Permian calcalkaline magmatism, which is the most striking feature of the overthrusting Doğanköy Nappe. Moreover, the amphibolite-facies metamorphic development of the pre-Triassic basement together with its Lower Triassic cover in this nappe and the presence of the Hamzabeyli Metagranite are additional supports for its distinctive geological history. Even if the pre-Triassic basements of the CIN were involved in the former Variscan orogeny, they all were originally in completely different geological settings.

The recognition of the differences in the Triassic stratigraphy of the CIN and the new fossil data are the most critical subjects of the present study. Overall, the Triassic successions represent an overstep sequence on the aforementioned Variscan basements. They disconformably commence with thick basal conglomerates containing pebbles from the underlying crystalline rocks and include passive margin platform sediments. A preliminary reconstruction based on rock units suggests that the Olenekian-Norian shallow-marine carbonates of the Sarpdere Nappe were deposited in a more proximal position on the platform then the carbonates of the Mahyadağ Nappe (Figs. 5 and 7).

The combined columnar section of the Doğanköy Nappe for the Triassic (Fig. 8) in the Turkish and Bulgarian areas, however, shows a completely different geological evolution. Disregarding the differences in metamorphism, the Doğanköy Nappe includes a coarse clastic-dominated lower part (Induan to Olenekian), followed by a clastic-carbonate deposition with volcanic interlayers of Olenekian age and finally a shallow-marine carbonate succession in the Anisian–Ladinian. These stratigraphic disparities cannot be assigned simply to lateral changes in depositional environment but would indicate, together with the discrete metamorphic evolution, that this unit was in a different geological position then the other CIN during the Triassic.

The identification of all these differences in stratigraphy was only possible by new fossil findings and one-to-one correlation of the fossiliferous Triassic successions both in Turkish and better dated (e.g. Sapunov et al. 1967; Dodekova & Chatalov 1982; Chatalov 1983, 1985, 1990; Chatalov & Trifonova 1985; Budurov & Trifonova 1991; Vasilev 1998, 2001; Boncheva & Chatalov 1998; etc.) locations in Bulgaria. For example, the Jurassic carbonates (the Kapaklı Dolomites of Çağlayan & Yurtsever 1998; Okay & Yurtsever 2006) are proven to be Late Triassic (the Karlık, the Kurudere and the Kapaklı Formations of different nappes) in age. The Triassic Mahya Schists of Çağlayan & Yurtsever (1998) covering large areas close to the Turkish-Bulgarian border, on the other hand, were shown to be Late Bajocian-Early Kimmeridgian in age by radiolarians. The Anisian-Ladinian age determined by Hagdorn & Göncüoğlu (2007) from crinoids also show that the Liassic age determined by echinoids in Çağlayan & Yurtsever (1998) is not correct.

The Jurassic overstep sequence on the Cimmerian tectonic units is rather uniform. It starts with basal conglomerates and rapidly grades into Sinemurian carbonates, which are also observed as olistoliths in the Pliensbachian-Aalenian clastics. The Late Bajocian-Early Kimmeridgian period is characterized by a thick succession of pyrite-rich black shales including levels of phosphate nodules that represent a change from anoxic to disoxic conditions, very probably in a restricted extensional basin. Towards the end of the Late Jurassic this basin closed and the basement rocks were imbricated by northward thrusting as a second phase (Fig. 9C,D). This event very probably resulted in crustal thickening and low-grade metamorphism that was followed after a considerable gap by Cenomanian-Santonian volcaniclastic rocks of the Srednogorie arc.

In contrast to the over generalized age assignments in previous studies we found belemnites, crinoids, pelecypoda in the Domuzpınartepe Formation; belemnites, bivalves (*Pseudopecten*) in the Gümüşalan Formation; crinoids in the Boztaş and the Yeşilce Formations and belemnites and radiolarian fauna in the Balaban Formation. In addition, Triassic foraminifers were found for the first time in the Kurudere Formation (Fig. 6.19, 21–22) of the Sarpdere Nappe, in the Taştepe Member (Fig. 6.15, 20) and the Kapaklı Formation (Fig. 6.13, 20, 25–29) and Jurassic foraminifers were found for the first time in the Domuzpınartepe Formation (Fig. 6.1–12).

Another important finding from the Turkish and the Bulgarian parts is that all the units described are definitely of continental crust type. No evidence of any kind of oceanic material that may represent an oceanic lithosphere has been found within or between the tectonic units. This is critical to note, as this observation contrasts with Natal'in et al.'s (2005) suggestions on the presence of serpentinite slices in the central part of the "Massif".

Preliminary structural evaluation

The nappe structure of the Istranca units in Turkey was already identified by Şengör et al. (1984) and Okay et al. (2001) in general terms. The detailed mapping during this study has resulted in recognition of a very complex structure, which will be presented in a forthcoming paper. The preliminary evaluation, however, indicates multiple periods of tectonic activities and thrusting. We therefore propose to omit the term "Istranca Massif" and to use the name Istranca Crystalline Complex (ICC) instead.

Conclusions

Geological mapping of the NW Turkish and SE Bulgarian parts of the Istranca "Massif" resulted in recognition of several tectonostratigraphic units with different Precambrian?-Paleozoic basements, Triassic, Jurassic and Upper Cretaceous overstep sequences. At least three compressional events — pre-Jurassic, post-Kimmeridgian and post-Campanian, respectively, have caused an intensive imbrication and created a very intricate structural complex of variable metamorphic rocks. We therefore suggest abandoning the term "Istranca Massif" and applying the name "Istranca Crystalline Complex" for this unit.

As a result of detailed stratigraphic work based on a number of new fossil findings and a detailed correlation with the better-dated formations in Bulgaria, three main tectonostratigraphic units were identified on the basis of different Triassic successions. As their primary imbrication is end Triassic in age, they were named as the Cimmerian Istranca Nappes comprising from bottom to the top the Sarpdere, Mahyadağ and Doğanköy Nappes. The first two nappes have dissimilar Variscan basements and a Lower Triassic cover, resembling passive margin successions that correlate with the Fore-Balkan terrane. The Doğanköy Nappe has a composite Variscan basement with metamorphic rocks of ortho- and para-origin and a Lower Triassic metasedimentary cover with medium–high-grade metamorphism. This suggests that the Doğanköy Nappe may represent a different unit, resembling the Rhodope terrane. The vergence of the CIN is towards the N.

The first common cover or overstep sequence of the CIN is the Lower Jurassic basement sediments. These platform type sediments laterally and vertically passes to the Gümüşalan Formation including an alternation of sandstone and siltstone with olistostromes and olistoliths of different origins possibly indicating an unstable platform margin.

The Jurassic rock units covering the CIN in Istranca have lost their primary structural positions due to the nappe movements that occurred in latest Jurassic-Early Cretaceous time. As a result they have been overthrust by Triassic successions, which they primarily covered, or locally form tectonic windows below them (Fig. 9C,D,E).

In brief, the preliminary data obtained by the recent fieldwork in the Istranca Crystalline Complex revealed new stratigraphic and structural implications. Even if preliminary, this new data will contribute to reconsideration of the previous suggestions and provide new constraints for the geodynamic evolution of this little known terrane assemblage in a very critical area of the Alpine belt.

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References

Aydın Y. 1974: Etude pétrographique et géochimique de la partie centrale du Massif d'Istranca (Turquie). *These l'Universitè de Nancy*, 1–131 (in French).

Aydın Y. 1982: Geology of Yıldız Mountains (Strandja) Massif. *ITU Fac. Eng. Arc. Thesis*, 1–107 (unpublished) (in Turkish).

Aydın Y. 1988: Geology of Yıldız Mountains (Strandja) Massif. *Selcuk Univ. Fac. Eng. Arch.* 2, 61–74 (inTurkish).

Aykol A. 1979: Petrology and geochemistry of Kırklareli-Dereköy Intrusion. *ITU Fac. Mining, Thesis,* 1–180 (in Turkish).

Baumgartner P.O., O'Dogherty L., Goričan Š., Dumitrică-Jud R., Dumitrică P., Pillevuit A., Urquhart E., Matsuoka A., Danelian T., Bartolini A., Carter E.S., De Wever P., Kito N., Marcucci M. & Steiger T. 1995: Radiolarian catalogue and systematics of Middle Jurassic to Early Cretaceous Tethyan genera and species. In: Baumgartner P.O., O'Dogherty L., Goričan Š., Urquhart E., Pillevuit A. & De Wever P. (Eds.): Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, systematics, biochronology. *Mém. Géol. Lausanne* 23, 37–685.

Bedi Y., Ergen A., Dogan A., Okuyucu C., Tekin U.K., Tuncay E., Kuscu İ., Ulusoy E., Türkmen Ö., Soycan H., Demiray D.G. & Göncüoğlu M.C. 2011a: Tectonostratigraphic features of the Istranca Crystalline Complex and their correlation with Bulgarian Successions: Preliminary findings from NW Turkey and SE Bulgaria. *64 th Geol. Congress of Turkey, Abstracts*, 28–29.

Bedi Y., Vasilev E., Dabovski C., Ergen A., Doğan A., Okuyucu C., Boncheva I., Sachanski V., Lakova I., Ivanova D. & Göncüoğlu M.C. 2011b: The napped structure of the Istranca Crystalline Complex in NW Turkey and SE Bulgaria. *3rd International Symposium on the Geology of the Black Sea Region, Bucharest, Abstracts*, 28–30.

Boncheva I. & Chatalov G.A. 1998: Paleozoic conodonts from the Dervent Heights and the Strandja Mountain, SE Bulgaria. *Compt. Rend. Acad. Bulg. Sci.* 51, 7–8, 45–48.

Budurov K. & Trifonova E. 1991: Stratigraphy of the Triassic in the Strandzha-Sakar region (South-East Bulgaria): conodont and foraminifera evidence. *Rev. Bulg. Geol. Soc.* 52, 3, 3–18.

Chatalov G.A. 1980: Two facies type of Triassic in Strandza mountain, SE Bulgaria. *Riv. Ital. Paleont.* 85, 1029–1046.

Chatalov G.A. 1983: New data of the age of the rocks of the Veleka group (Strandja Mountain). *Compt. Rend. Acad. Bulg. Sci.* 36, 7, 927–930.

Chatalov G.A. 1984: A contribution to the stratigraphy and lithology of the Triassic system in Teteven Anticlinorium. *Paleont., Stratigr., Lithol.* 19, 51–64 (in Bulgarian).

Chatalov G.A. 1985: Stratigraphy of Strandzha-type Triassic (Strandzha Mountain, southest Bulgaria). *Geol. Balcanica* 15, 6, 3–38.

Chatalov G.A. 1988: Recent developments in geology of the Strandzha zone in Bulgaria. *Bull. Tech. Univ. Istanbul* 41, 433–465 (in Turkish).

Chatalov G.A. 1990: Geology of the Strandja Zone in Bulgaria. *Publ. House Bulg. Acad. Sci.*, 1–263 (in Bulgarian).

Chatalov G.A. & Trifonova E. 1985: Contribution to the stratigraphy of the Balkanide type Triassic in Sveti Ilija Ridge and Strandzha Mountain (SE Bulgaria). *Rev. Bulg. Geol. Soc.* 156, 3, 312–324.

Cheshitev G. & Kancev I. 1989: Geological map of P.R. Bulgaria, 1 : 500,000. Committee of Geology. *Department of Geophysical Prospecting and Geological Mapping, Sofia,* Bulgaria.

Chiari M., Baumgartner P.O., Bernoulli D., Bortolotti V., Marcucci M., Photiades A. & Pirincipi G. 2012: Late Triassic, Early and Middle Jurassic radiolaria from ferromanganese-chert 'nodules' (Angelokastron, Argolis, Greece): evidence for prolonged radiolarite sedimentation in the Maliac-Vardar Ocean. *Facies,* Doi: 10.1007/s10347-012-0314-4

Çağlayan M.A. 1996: Evolution of Strandja Massif in Mesozoic-Lower Tertiary and its role in the evolution of Thrace Basin. *Bull. Turkish Assoc. Petrol. Geol.* 81, 82–93.

Çağlayan M.A. & Yurtsever A. 1998: Burgaz-A3, Edirne-B2 and B3; Burgaz-A4 and Kırklareli-B4; Kırklareli-B5 and B6; Kırklareli-C6 Maps, 1 : 100,000 scaled geologic maps of Turkey, No.: 20, 21, 22, 23, *MTA Publ.*, Ankara (in Turkish).

Dabovski C. & Savov S.S. 1988: Structural studies in the nappes of Southeast Strandza. *Geol. Balcanica* 18, 19–36.

Dabovski C. & Zagorchev I. 2009: Introduction: Mesozoic evolution and Alpine structure. In: Zagorchev I., Dabovski C. & Nikolov T. (Eds.): Geology of Bulgaria. Volume II, Part 5. Mesozoic geology. *Prof. Marin Drinov Academic Publishing House,* Sofia, 15–37.

Dabovski C., Chatalov G.A. & Savov S.S. 1990: The Strandzha Cimmerides in Bulgaria. In: Savascin M.Y. & Eronat A.H. (Eds.): *International Earth Sciences Congres on Aegean regions*, İzmir, 92–101.

Dabovski C., Boyanov I., Khrischev K., Nikolov T., Sapunov I., Yanev Y. & Zagorchev I. 2002: Structure and Alpine evolution of Bulgaria. *Geol. Balcanica* 32, 9–15.

Dodekova L. & Chatalov G.A. 1982: Dinoflagellates from Middle Jurassic sediments in the village of Kalovo environs, Strandja Mountain. *Compt. Rend. Acad. Bulg. Sci.* 35, 5, 669–672.

Dumitrică P. & Dumitrică-Jud R. 2005: *Hexasaturnalis nakasekoi* nov. sp., a Jurassic saturnalid radiolarian species frequently confounded with *Hexasaturnalis suboblongus* (Yao). *Rev. Micropaleont.* 48, 159–168.

Elmas A., Yılmaz I., Yiğitbaş E. & Ullrich T. 2010: A Late Jurassic–Early Cretaceous metamorphic core complex, Strandja Massif, NW Turkey. *Int. J. Earth Sci.,* Doi: 10.1007/s00531-010-0540-3

Gerdjikov I. 2005a: Thrust tectonics in Strandja Zone: New data from the Dervent Heights, SE Bulgaria. *Ann. Univ. Mining and Geol., Geol. Geophys.* 48, 1, 41–46 (in Bulgarian).

Gerdjikov I. 2005b: Alpine metamorphism and granitoid metamorphism in the Strandja Zone: New data from the Sakar Unit, SE Bulgaria. *Turkish J. Earth Sci.* 14, 167–183.

Gocev P.M. 1985: Strandzides. *Geotectonics*, *Tectonophysics and Geodynamics* 18, 28–54.

Gocev P.M. 1991: Some problems of nappe tectonics of Strandzhides in Bulgaria and Turkey. *Bull. Technical Univ. Istanbul* 44, 137–164.

Göncüoğlu M.C., Dirik K. & Kozlu H. 1997: General characteristics of pre-Alpine and Alpine Terranes in Turkey: Explanatory notes to the terrane map of Turkey. *Ann. Geol. Pays Hellen.,* 37, 515–536.

Hagdorn H. & Göncüoğlu M.C. 2007: Early-Middle Triassic echinoderm remains from the Istranca Massif, Turkey. *Neu. Jb. Geol.-Paleont. Abh.* 246, 2, 235–245.

Kamenov B., Vergilov V., Genov I., Savov S., Dabovski H., Ivchinova L., Vergilov I. & Andreev A. 1986: Geological structure and petrographical peculiarities of the Lessovo orthometamorphic complex. *Strandzha-Sakar Collection,* Yambol 4, 8, 145–157 (in Bulgarian).

Kiessling W. 1999: Late Jurassic radiolarians from the Antarctic Peninsula. *Micropaleontology* 45, 1, 1–96.

Kozhoukharov D. 1987: Lithostratigraphy and structure of the Precambrian metamorphics from the core of Bjala-reka Dome, East Rhodope Mts. *Geol. Balcanica* 17, 2, 15–38 (in Russian).

Ksiazkiewicz F. 1930: Geology of Strandja and surrounding areas. *Sci. Res. Voyage of the Orbis,* Krakow, 3, 1–28.

Maliakov 1997: Data about Paleozoic age of the low grade metamorphic rocks in south-Eastern Strandja. *Ann. Univ. Mining Geol.* 41, 1, 119–122 (in Bulgarian).

Moore W.J., Mc. Kee E.H. & Akinci Ö. 1980: Chemistry and chronology of plutonic rocks in the Pontid mountains, northern Turkey. *Europen Cooper Deposits Congress Book*, Belgrade, 209–216.

Natal’in B.A. 2006: Paleozoic evolution of the northern margin of Paleo-Tethys. In: Tomurhuu D., Natal’in B., Ariunchimeg Y., Khishigsuren S. & Erdenesaikhan G. (Eds.): Second International Workshop and Field Excursions for IGCP Project-480. Structural and Tectonic correlation across the Central Asian Orogenic Collage: Implications for Continental Growth and Intracontinental Deformation. *Abstracts and Excursion Guide Book*: *Ulaanbaatar, Institute of Geology and Mineral Recourses, Mongolian Academy of Sciences,* 33–36.

Natal’in B.A., Satır M., Sunal G. & Toraman E. 2005: Structural and metamorphic evaluation of the Strandja Massif. *Final report of the 101Y010 Project, Türkiye Bilimsel ve Teknik Araştırma Kurumu, Yer Deniz Atmosfer Bilimleri ve Cevre Araţtırma grubu,* Ankara, 1–183.

Nikolov G., Rankova T., Antova N. & Chemberski C. 1996: Tectonostratigraphical analysis of SE Bulgaria: *Congr. Bulg. Geol. Soc.*, *Abstr*., Sofia, 119–120.

Okay A. & Yurtsever A. 2006: Metamorphic rock units of Strandja Massif with post metamorphic Cretaceous rock units. Lithostratigraphic units of Thrace region. Committee of Stratigraphy Lithostratigraphic Units, Series 2. *General Directorate of Mineral Research and Exploration Publications*, 1–41.

Okay A., Tüysüz O. & Akyüz H.S. 1995: Geology and tectonics of western part of Strandja Massif. *TPAO Report* 3521, 1–108 (unpublished) (in Turkish).

Okay A., Satır M., Tüysüz O., Akyüz S. & Chen F. 2001: The tectonics of the Strandja Massif: late-Variscan and mid-Mesozoic deformation and metamorphism in the northern Aegean. *Int. J. Earth Sci.* 90, 217–233.

Pamir H.N. & Baykal F. 1947: Geological structure of Strandja Massif. *MTA Report,* 2257 (unpublished) (in Turkish).

Pessagno E.A. Jr., Blome C.D. & Longaria J.F. 1984: A revised radiolarian zonation for the Upper Jurassic of Western North America. *Bull. Amer. Paleont.* 87, 320, 1–51.

Pessagno E.A. Jr., Blome C.D., Mayerhoff Hull D. & Six W.M. 1993: Jurassic radiolaria from the Josephine ophiolite and overlying strata, Smith River subterrane (Klamath Mountains), northwestern California and southwestern Oregon. *Micropaleontology* 39, 2, 93–166.

Petrova A. & Simeonov A. 1988: Zelenkovska Formation, a new formation of Varsilo Group (Upper Cretaceous Series, Northeast Strandza Mountain). *Rev. Bulg. Geol. Soc.* 49, 3, 95–98 (in Bulgarian).

Petrova A., Vasilev E., Mihailova L., Simeonov A. & Chelebiev E. 1980: Lithostratigraphy of a part of the Upper Cretaceous in the Burgas region. *Geol. Balcanica* 10, 4, 23–67 (in Russian).

Sapunov I.G. 1999: The Jurassic in the South-eastern part of Bulgaria (stratigraphy, geodynamics, facies and paleogeographic evolution). *Geol. Balcanica* 29, 19–59.

Sapunov I., Tchoumathenco P. & Shopov V. 1967: Biostratigraphy of the Lower Jurassic rocks near the village of Komshtitsa, district of Sofia (Western Bulgaria). *Bull. Geol. Inst., Ser. Geotectonics, Stratigraphy and Lithology* 16, 125–143 (in Bulgarian).

Sunal G., Natal’in B., Satır M. & Toraman E. 2006: Paleozoic magmatic events in Strandja Massif, NW Turkey. *Geodinamica Acta* 19, 283–300.

Sunal G., Satır M., Natal’in B., Topuz G. & Vonderschmidt O. 2011: Metamorphism and diachronous cooling in a contractional orogen: the Strandja Massif, NW Turkey. *Geol. Mag.,* 1–17, Doi: 10.1017/S0016756810001020

Şengör A.M.C., Yılmaz Y. & Sungurlu O. 1984: Tectonics of the Mediterranean Cimmerides: nature and evolution of the western termination of Paleo-tethys. In: Dixon J.E. & Robertson A.H.F. (Eds.): The geological evolution of the Eastern Mediterranean. *Geol. Soc. London., Spec. Publ.* 17, 77–112.

Tronkov D. 1975: Notes on the Triassic stratigraphy in the Golo-Bardo Mountain. *Paleont., Stratigr., Lithol.* 1, 71–84 (in Bulgarian).

Üşümezsoy Ş. 1982: Petrogenetic evolution of Strandja Massif. *Istanbul Univ. Fac. Geosci. Ph.D. Thesis*, 1–194 (in Turkish).

Üşümezsoy Ş. 1990: Strandja Orogeny; Circum Black Sea Cimmerian orogenic belts and massive sulphide deposits. *Geol. Bull. Turkey* 33, 17–28 (in Turkish).

Vasilev E. 1998: Kushliovo Formation, a new Formation in the Grahilovo Subgroup (Veleka Group, Strandjian type type Triassic), Central Strandja Mountain. *Rev. Bulg. Geol. Soc.* 2, 92–94.

Vasilev E. 2001: New data about Bosna Subgroup stratigraphy (Veleka Group, Tethys type Triassic, allochthone) in Strandzha Mountain, SE Bulgaria. *Rev. Bulg. Geol. Soc.* 62, 1–3, 99–110.

Vasilev E. & Dabovski C. 2010: Tectonostratigraphy of Strandzha Massif: Correlations across the Türkish-Bulgarian Border. *BAS Guide Book*, 1–58.

Vergilov V., Kamenov B., Haydoutov I., Savov S., Vergilov I. & Ivchinova L. 1986: Petrology and structure of Sakar batholith, Lessovo granites from the region of Radovec village and of the seperate intrusive bodies in the region of Tundza River, Sofia. *Report DSO “Redki metali”, Geofond SU*.

Yanev S., Göncüoğlu M.C., Gedik İ., Lakova I., Boncheva I., Sachanski V., Okuyucu C., Özgül N., Timur E., Maliakov Y. & Saydam G. 2006: Stratigraphy, correlations and palaeogeography of Paleozoic terranes of Bulgaria and NW Turkey: a review of recent data: In: Robertson A.H.F. & Mountrakis D. (Eds.): Tectonic development of the Eastern Mediterranean Region. *Geol. Soc. London, Spec. Publ.* 260, 51–67.