# ANALYSIS OF THE EARLY ALPINE STRUCTURAL FRAMEWORK OF THE CENTRAL PART OF THE STRANDZHA ZONE

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**ABSTRACT.** A critical analysis is offered of the available geological data for one of the least studied parts of the Strandzha Zone that occupies the area between the Tundzha River and the Central Strandzha Mountains. An important part of the analysis includes the compilation of a summary map integrating 1:100 000 scale geological maps of territories on either side of the frontier. The cross-border correlation of Pre-Upper Cretaceous units is based on a synthesis of recently published geochronological data along with the results of our new field studies. This allows not only a better understanding of the geological evolution and the structure of the Strandzha Zone but also some correlations to be made between the major tectonic units of the zone in Bulgaria and Turkey. In line with previous models, an autochthon and an allochthon tectonic unit is distinguished in the study area. While in its western and southern parts of the autochthon the rocks record intensive Early Alpine metamorphism and deformation, eastward they are affected by a much weaker tectonic overprint that does not lead to obliteration of the primary fabric. The allochthonous units are characterised by specific syn-metamorphic fabric. Defining the extent of the allochthonous units emerges as the most acute tectonic problem.

**Key words**: Strandzha zone, Alpine tectonics, cross-border correlation, tectonics

**АНАЛИЗ НА РАННОАЛПИЙСКАТА СТРУКТУРНА РАМКА ЗА ЦЕНТРАЛНАТА ЧАСТ НА СТРАНДЖАНСКАТА ЗОНА**

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**РЕЗЮМЕ.** Направен е критичен анализ на съществуващите геоложки данни за една от най-слабо изучените части на Странджанската зона, която заема пространството между река Тунджа и Централна Странджа. Важна част от работата е компилирането на обобщена геоложка карта в М 1:100 000, включваща териториите от двете страни на държавната граница. Трансграничната корелация на до-горнокредните единици е базирана на интегриране на новите геохроноложки данни, както и на теренните ни изследвания. Това позволява не само по-добро разбиране на структурата и геоложката еволюция на Странджанската зона, но и дава възможност да се направят корелации между главните тектонски единици в България и Турция. Следвайки предложените по-ранно тектонски модели и в нашата работа разграничаваме автохтонни и алохтонни единици. Западните и южните автохтонни единици запечатват интензивен алпийски метморфизъм и син-метаморфни деформации. Източните части на автохтона са практически лишени от метаморфни изменения. Алохтонните единици се характеризират със специфична синметаморфна структура. Дефинирането на точния обхват на алохтонните единици се очертава като най-сериозен тектонски проблем.

**Key words**: Странджанска зона, Алпийска тектоника, трансгранична корелация, тектоника

## Introduction

The presence of metamorphosed Mesozoic rocks in the Strandzha Zone are already known from the pioneering studies of Yanischevski (1946). Their metamorphism was caused by tectonic processes that took place during the Late Jurassic and Early Cretaceous and which were ascribed equally as part of the Cimmerian or Early Alpine orogeny (e.g. Chatalov 1990; Gerdjikov, 2005; Natal'in et al., 2016). These processes were related to the formation of the large-scale thrust structures that define the present-day tectonic frame of the Strandzha Zone (e.g. Dabovski & Savov, 1988). While these major features are more or less well documented in the eastern Strandzha, their presence and extent in the Dervent Heights and the rest of the Western Strandzha are still poorly studied. Studies on the synmetamorphic structures associated with the Early Alpine metamorphism in this area, as well as some of the neighboring tectonic zones west of it, are still missing.

The aim of this study is to provide a novel and more rational interpretation of the structural framework and geological evolution of the central part of the Strandzha Zone. The achievement of this preliminary synthesis was possible by the integration of the previously published data combined with detailed new field studies and a structural analysis. New geochronological analyses of key rock formations from the main tectonic units are envisaged in the future.

## Main geological units

The Strandzha Zone in Bulgaria includes three main tectonic units: the Sakar, the Strandzha, and the Veleka units. The subdivision was based on their lithological characteristics and different structural position during the Late Jurassic to Early Cretaceous thrusting and metamorphism (e.g. Chatalov, 1990; Gerdjikov, 2005). The Sakar unit, characterised by the presence of high-grade metamorphosed Precambrian to Triassic rocks, is the one innermost within the frame of the Alpine Balkan orogen. The Early Alpine metamorphism reached amphibolite facies conditions which are the higher most within the Strandzha Zone. Eastward, in the Strandzha unit, the Early Alpine metamorphism is less intensive and widespread. For the moment, it is impossible to put precise tectonic boundary between the Sakar and the Strandzha units. As such, it is usually assigned the Lesovo fault (Chatalov, 1965) which is detected only on the basis of sharp lithological changes across its trace (Fig. 1). The Strandzha unit is overthrust by the metamorphic rocks of the Veleka allochthon unit (e.g. Dabovski and Savov, 1988). This allochthon represents probably the least studied unit where its stratigraphy, age of the rock associations, and their metamorphic degree are still poorly constrained and under debate.

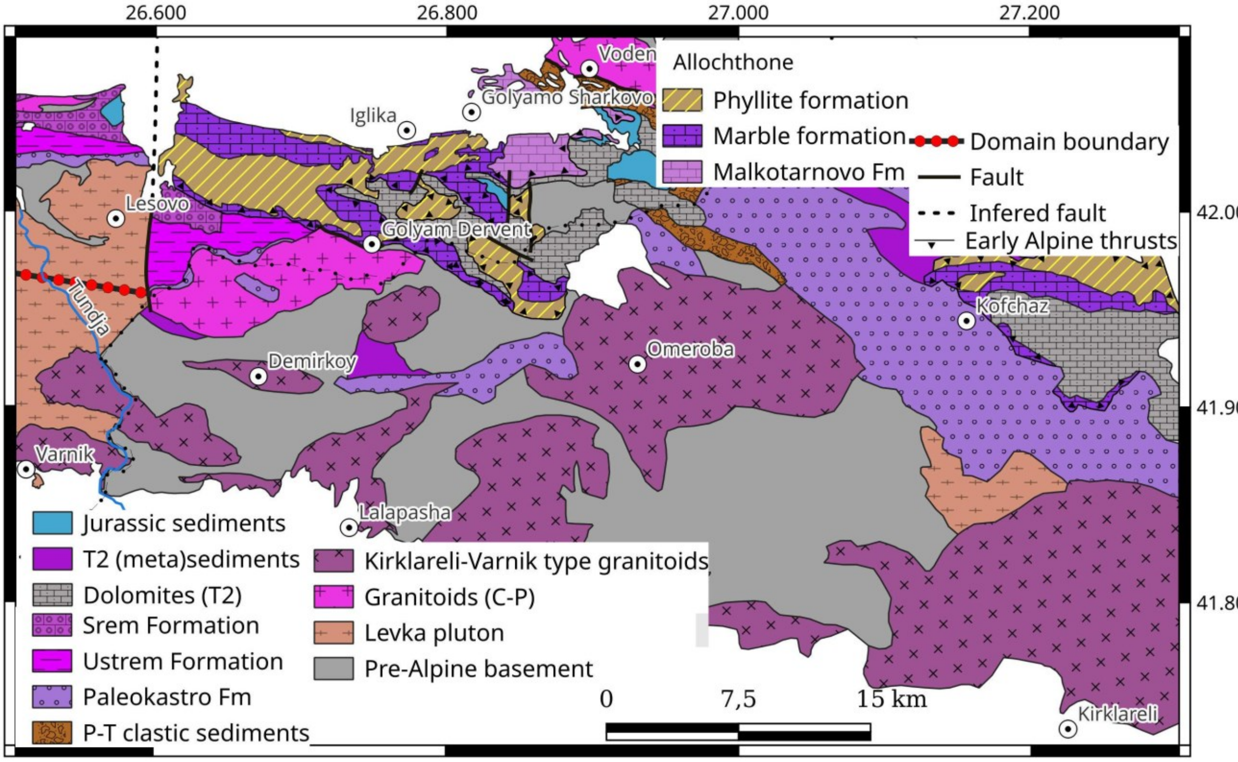


**Fig. 1. Simplified geological map of the central part of the Strandzha Zone. The possible continuation of the Veleka unit to the south is speculative. Also, for the part south of the border, another speculation is the attribution of the Mesozoic units to a given stratigraphic unit that originates from Bulgarian research. The Malko Tarnovo Formation is shown as part of the allochthon, despite unclear position. An attempt was made to simplify and omit parts of the complications introduced in Dabovski et al. (1993), that are not present in the original maps at scale 1: 25 000.**

## Redefinition of the autochthonous units

Four Alpine litho-tectonic entities have been identified in the study area, based on their different lithological characteristics and structural positions: the Sakar autochthon, the western Dervent autochthon, the Western Strandzha autochthon, and the Veleka allochthon.

The Sakar autochthon occupies the western part of the area (Fig. 1). The Levka pluton, also known as the Lesovo orthogneisses (Dabovski et al., 1993), which is ca. 319 Ma old, is cropping out to the south, intruded by a set of smaller bodies of K-feldspar phyric granites, or Varnik granites (Gerdjikov, 2005). The Varnik granites share some similar features with the well-studied Permian Kirklareli pluton in Turkey (Natal'in et al., 2016) with which they share probably a similar age. The Levka pluton intrudes the Pre-Permian high-grade basement affected by Variscan and Alpine metamorphic events (e.g. Sałacińska et al., 2022). Northward, granites and their host rocks are covered by Early to Middle Triassic metasediments (Fig. 1) that can be regarded as an eastern continuation of the well-studied Triassic sequences from the Topolovgrad syncline.

The western Dervent autochthon occupies the western and central parts of the Dervent Heights. They are dominated by the large (50 km$^2$) granitoid body of the Dervent-Hamzabeyli pluton that, unlike the neighboring Levka pluton, does not display a penetrative Alpine overprint (Gerdjikov and Metodiev, 2005). The Dervent-Hamzabeyli granite is emplaced into high-grade gneisses currently cropping out along the NE and SE periphery of the pluton (Fig. 1). While the part of the northern contact of the pluton is strongly overprinted by late brittle deformation, along its northwestern contact transgressive Triassic metasediments are preserved (Fig. 1). Despite the poor outcrop conditions, the field data confirm these relationships and the presence of Middle Triassic sequences. It is important to be noted that the metamorphic grade of these sediments is lower than those of the Sakar autochthon and this fact corroborates well with the low-strain deformation observed in the Dervent-Hamzabeyli pluton. Thus, it could be concluded that an important change in the metamorphic grade exist across the Lesovo fault.

The western Strandzha autochthon is cropping out in the easternmost Dervent Heights and the westernmost Strandzha Mountains (east of the meridian of Golyamo Sharkovo - Fig. 1). It represents the western limb of the Central Strandzha anticline (Yanischevski, 1946), with a generally well-preserved Early Alpine structure. Here, the Triassic sequences slightly differ from these in the Sakar unit but are similar to those of eastern Strandzha. The presence of Jurassic sediments in this unit is also well-proven (Dabovski et al., 1993). The absence of metamorphic alterations is probably the most striking contrast with the Mesozoic rocks from the other autochthon units in the study area.

While well-studied and defined in the East Strandzha, there is a general problem with the definition of the boundaries and the lithological contents of the allochthonous Veleka unit in the area of the Dervent Heights. This is mostly due to the fact that the extent of the allochthon in this area was defined on the basis of paleontological findings only and not on structural data and detailed field observations (e.g. Dabovski et al., 1993). In a previous contribution by Gerdjikov and Metodiev (2005), doubts were cast on the preceding ideas proposed on the structure of the Veleka unit.

## Materials and methods

An important part of the studies presented herein is the accomplishment of a compiled map based on the integration of the existing 1:100 000 scale geological map sheets together with other available geological maps from Bulgaria and Turkey (Dabovski et al., 1993; Çağlayan and Yurtsever, 1998). The map is elaborated in the open-sourced QGIS software and is supplemented with our own data from the field studies. The field studies were carried out intermittently in the period 1998-2024. Observations of the tectonic contacts, lithological relationships, shear zones geometry, planar and linear fabric orientations are conducted in more than 300 outcrops.

## Results

**Compiled geological map**

The compiled geological map integrating the results of the recently published studies from the Turkish and Bulgarian part of Strandzha Zone (e.g. Sunal et al., 2011; Natal'in et al., 2016; Sałacińska et al., 2022) shows the distribution of the main lithotectonic units in the study area (Fig. 1). Often there is a good corroboration between the geological data of both sides of the border, as in some cases there is a perfect match of the geological boundaries which allows correlations to be made between the main geological features (e.g. between the Dervent and the Hamzabeyli plutons, the SW margin of the Central Strandzha batholith and the Kula pluton, the eastward continuation of the Varnik-type granites, etc.). In other cases, there are differences in the interpretation of the age and geological evolution of rock formations belonging to apparently similar geological units. Changes of the stratigraphic age of sedimentary sequences across the border were also identified. Some of these inconsistencies could be partly due to the low resolution of the geological maps of the Turkish part of the Strandzha Zone. Further field, structural, and geochronological analyses are necessary in order to solve these problems.

**The extent of the Sakar unit**

In the previous studies, the Lesovo fault was conveniently designated as the eastern boundary of the Sakar autochthon (e.g. Chatalov, 1990). The existing cross-border maps and mainly the geological data from the Turkish side (Sunal et al., 2011; Elmas, 2012; Natal'in et al., 2016) give grounds for rejecting this paradigm. It is obvious that the Sakar-type basement, characterised by its high-grade Early Alpine overprint, extends eastward at least to the region of Kirklareli in Turkey (Fig. 1). This suggestion is supported also by the presence of the strip aligned in E-W direction, from the Sakar unit up to Kirklareli, which is of Late Carboniferous-Permian, most often strongly foliated, with granitoids intruding this high-grade metamorphic basement of a probable Variscan age (Fig. 1). The basement is referred to as the Zhaltichal Formation in Bulgaria (Dabovski et al., 1993) and the Tekedere Group in Turkey (Çağlayan and Yurtsever, 1998). As in the northern part of the Sakar unit in Bulgaria, north of Kirklareli (Fig. 1), the high-grade basement and granitoids are covered by strongly deformed and metamorphosed Permian to Triassic sequences (Natalin et al., 2012).

At this stage of the research, it was not possible to define the limit of the Sakar unit in the area northwest of Kirklareli. It is not clear yet whether there is a transition zone or an abrupt contact between the rocks affected by higher- and lower-grade Early Alpine metamorphism and deformation. Some hints for a gradual transition are given by the data of Sunal et al. (2011), who suggest a lowering of the peak metamorphic temperatures in the area from the south to the north. On the other hand, in the published geological maps, there are several E-W trending faults and shear zones that can play the role of the northern limit of the Sakar unit in the Turkish part of the Strandzha Zone.

Bedi et al. (2013) interpreted the Sakar unit (their Dogankoy nappe) as occupying the uppermost tectonic position within the Strandzha Zone. For the moment, such interpretation is suggested only for the Turkish part of the unit, whereas clear structural data are still missing. On the other hand, it seems that the Sakar unit occupies the lowermost tectonic position in Bulgaria since the Sakar-type Middle Triassic marbles are tectonically overridden by Lower Jurassic non-metamorphosed sediments typical for the Strandzha unit, as in the area of the village of Melnitsa (Dabovski et al., 1993), as well as by rocks of the Veleka allochthon unit.

**Synmetamorphic Alpine fabric in the autochthonous units**

Data on the synmetamorphic fabric of the studied rocks are available only for the westernmost part of the area, west of the Lesovo fault (Gerdjikov, 2005). Two structural domains can be distinguished there. The first, a compressional-transpressional domain described in the southern part of the Sakar unit, is characterised by the presence of high-grade shear zones parallel to the general trend of the regional foliation which strikes E-W and dips moderately to the SE and S. Numerous shear-sense criteria are observed, including asymmetric porphyroclasts and S-C' fabrics, all showing top-to-the-NW-N sense of shear. The structural data from Turkey indicate that this domain probably continuous to the east, whereas it is studied only in the region of Kirklareli for now (Sunal et al., 2011).

While the compressional-transpressional domain is built almost exclusively of metagranitoids and Precambrian to Paleozoic rocks, the second one, situated north of the first one (Fig. 1), includes a metamorphosed Triassic cover as well. This domain is characterised by generally north- to northeast dipping foliation and the lack of high-grade strike-slip shear zones. The lineation is less frequently developed and is plunging towards NE to N. The kinematic criteria are rarely observed and point to a top-to-the-N shearing. This is consistent with general northward decreasing of the degree of metamorphic alterations. The transition between the two domains is gradual and marked by the presence of a heterogeneously sheared volume, dominated by steep foliation, in the Carboniferous granitoids (Fig. 1).

There are no published data on the synmetamorphic fabric in the autochthonous units east of the Lesovo fault in Bulgaria. Field observations from rocks in this area, which are well defined as part of the autochthon (e.g. the western Dervent autochthone) indicate the presence of low-temperature shear zones of up to decameter-scale, which can be interpreted as related to the Alpine deformation. In any case, this part of the autochthon records lower in its intensity Alpine reworking.

**Delineation and internal synmetamorphic structure of the Veleka allochthon in the Dervent Heights**

The map interpretation of the distribution of autochthonous and allochthonous rocks in the study area is still preliminary

(Fig. 1), yet based on several field trips and on a previous study of key areas around the village of Golyam Dervent (Gerdjikov and Metodiev, 2005). The main difficulties are related to the accessibility of the countryside (due to depopulation, the area of the Dervent Heights is turning overgrown and impassable) and general poor outcrop conditions. The distribution of allochthonous rocks in Turkey, presented on the map, is mostly interpretative for the time being.

As a coherent body, the allochthon is mapped west of the line connecting the villages of Golyam Dervent and Golyamo Sharkovo. In this area, its relationships with the autochthon can be observed in several outcrops and along several sections. East of this line, the situation is more complicated and allochthonous rocks occur as "patches" since their contacts are often marked by late, brittle faults. To trace the distribution of the Veleka unit in Turkey, the only available source for now is the Turkish 1:100 000 scale geological map (Çağlayan and Yurtsever, 1998). The analysis of this map indicates that north of Omeroba there is a large area built only of autochthonous rocks (Fig. 1). According to this map, allochthonous rocks occur only north of Kofchaz (Fig. 1). Thus, it appears that the outcrops of the Veleka unit in the Dervent Heights are forming a km-scale klippe, completely detached from other parts of the allochthon.

In general, the logic of Dabovski et al. (1993) is followed, and two allochthonous sheets (designated as formations) are distinguished: lower – marble dominated, and upper – phyllite dominated. It must be noted that this superposition is rarely obvious, as probably the best arguments for this are from the area NW and W of Golyam Dervent (Gerdjikov and Metodiev, 2005).

Unlike the autochthon, the Phyllite and Marble formations display strong mylonitic fabric. The constituent rocks (phyllites, marbles, and calc-schists) are strongly foliated and stretching lineation is often observed. In the areas where coherent sections of the allochthon could be observed (e.g. NW of Golyam Dervent, S of Golyamo Sharkovo and Iglika), foliation trends ESE-WNW to E-W and the lineation is plunging either to WNW or ESE. Different scale coaxial folds with axes trending parallel to the lineations were observed.

**The problem of distinction between the autochthonous and allochthonous units**

The absence of clear field evidence for the existence of a discrete thrust boundary between the autochthon and the allochthon has made their distinction on the field very difficult. Therefore, this boundary could be defined in the study area only on the basis of the differences in the lithological and metamorphic characteristics. Unfortunately, this is not an easy task and straightforward conclusions are often difficult to be made. Although the lithological associations of the allochthon in the Dervent Heights are relatively well defined, their distinction from apparently lithologically similar units from the autochthon is very difficult. This is the case, for example, with the Phyllite and Marble formations due to the existence of the same lithologies in the neighboring units. After numerous field trips and detailed mapping in the study area, the allochthon position of the Phyllite formation could be affirmed with certainty only in the area northwest of the village of Golyam Dervent (Gerdjikov and Metodiev, 2005).

Another possibility to distinguish the lithologically similar units from the autochthon and the allochthon is comparisons of their style of deformation and degree of metamorphism. This demands detailed structural studies of the rocks from the study area to be made. All synmetamorphic features (S and L fabrics, and folds) of the Phyllite and Marble formations in the Dervent Highs Heights show characteristics and orientations similar to those from the allochthonous units in the eastern part of the Strandzha Zone (work in preparation).

**Concluding remarks**

Studies in the central part of the Strandzha Zone put in evidence the existence of three autochthonous units and an allochthonous unit consisting of Phyllite and Marble formations, which is related to the Early Alpine orogeny. The intensity of the Early Alpine metamorphism and deformation in the autochthon clearly decrease eastward from the Sakar to the Western Strandzha unit. Structural observations from the allochthon in the Dervent Heights show clear similarities of their deformation style and structural position with the rocks from the Veleka allochthon unit in the Eastern Strandzha.

Finally, this study demonstrates that even simple attempts for cross-border correlations based mostly on the compilation of different geological maps from Bulgaria and Turkey can be highly beneficial for the creation of a meaningful tectonic synthesis.

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## References

Bedi, Y., Vasilev, E., Dabovski, C., Ergen, A., Okuyucu, C., Dogan, A., TEKİN, U.K., Ivanova, D., Boncheva, I., Lakova, I., Sachanski, V. (2013). New age data from the tectonostratigraphic units of the Istranca Massif in NW Turkey: a correlation with SE Bulgaria. *Geol. Carpathica 64* (4), 255–277.

Çağlayan, M. A., & Yurtsever, A. (1998). *Geological Map of Turkey 1:100,000 scale, no. 20, 21, 22, 23, Burgaz-A3, Edirne-B2 and B3, Burgaz-A4 and Kırklareli-B4; Kırklareli-B5 and B6; Kırklareli-C6 Sheets*. Ankara, Mineral Research and Exploration Institute (MTA) of Turkey.

Chatalov, G. (1965). New tectonic structures in the area between the Sakar and the Strandzha mountains. *Comptes Rendus de l'Academie Bulgare Des Sciences*, *18*, 861–864.

Chatalov, G. (1990). *Geology of the Strandzha zone in Bulgaria* (pp. 1–263). Publ. House Bulg. Acad. Sci.

Dabovski, C., Savov, S., Chatalov, G., & Shilyafov, G. (1993). *Explanatory note to the geological map of Bulgaria in scale 1:100,000. Map sheet "Edirne"*. Geology and Geophysics Co, Sofia [in Bulgarian].

Dabovski, H., & Savov, S. S. (1988). Structural studies in the nappes of Southeast Strandža. *Geologica Balcanica*, *18*, 19–36.

Elmas, A. (2012). Basement types of the Thrace Basin and a new approach to the Pre-Eocene tectonic evolution of the northeastern Aegean and northwestern Anatolia: A review of data and concepts. *International Journal of Earth*

*Sciences*, *101*(7), 1895–1911. https://doi.org/10.1007/s00531-012-0756-5

Gerdjikov, I. (2005). Alpine metamorphism and granitoid magmatism in the Strandzha zone: New data from the Sakar unit, SE Bulgaria. *Turkish Journal of Earth Science*, *14*, 167–183.

Gerdjikov, I., & Metodiev, D. (2005). Thrust tectonics in the Strandzha zone: New data from the Dervent Heights, SE Bulgaria. *Ann. Univ. Mining and Geol., Geol. Geophys*, *48, 1*, 41–46 [in Bulgarian].

Natal'in, B. A., Sunal, G., Gün, E., Wang, B., & Zhiqing, Y. (2016). Precambrian to Early Cretaceous rocks of the Strandzha Massif (northwestern Turkey): Evolution of a long lasting magmatic arc. *Canadian Journal of Earth Sciences*, *53*(11), 1312–1335. https://doi.org/10.1139/cjes-2016-0026

Natalin, B., Sunal, G., Satir, M., & Toraman, E. (2012). Tectonics of the Strandzha Massif, NW Turkey: History of a Long-Lived Arc at the Northern Margin of Palaeo-Tethys. *Turkish Journal of Earth Sciences*. https://doi.org/10.3906/yer-1006-29

Sałacińska, A., Gerdjikov, I., Kounov, A., Chew, D., Szopa, K., Gumsley, A., et al. (2022). Variscan magmatic evolution of the Strandzha Zone (Southeast Bulgaria and Northwest Turkey) and its relationship to other North Gondwanan margin terranes. *Gondwana Research*. https://doi.org/10.1016/j.gr.2022.04.013

Sunal, G., Satir, M., Natal'In, B. A., Topuz, G., & Vonderschmidt, O. (2011). Metamorphism and diachronous cooling in a contractional orogen: The Strandzha Massif, NW Turkey. *Geological Magazine*, *148*(4), 580–596. https://doi.org/10.1017/S0016756810001020

Yanischevski, A. (1946). Aperçu abrege sur la Geologie de la montagne Strandzha dans le Bulgarie de sud-est. Geologie de la Bulgarie. *Annuaire de la Direction pour recherches Geologiques, Ser. A*, *4*, 380–389 [in Bulgarian].