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DISCUSSION

Comment on Georgiev et al. "Structure and U–Pb zircon geochronology of an Alpine nappe stack telescoped by extensional detachment faulting (Kulidzhik area, Eastern Rhodopes, Bulgaria)

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Abstract In this discussion, we evaluate the field, chemical, sedimentary, structural and metamorphic data related to the Kulidzhik area tectonic proposal.

Keywords Kulidzhik area · Eastern Rhodope · Bulgaria

Introduction

Going back to April 2008, when a joint field day with Neven Georgiev, Nikolaus Froitzheim and Thorsten Nagel was conducted by the principal author on their request in the Kulidzhik river valley, the principal author now sees that the geology of the area has attracted the colleague's attention resulting in a recent paper titled "Structure and U–Pb zircon geochronology of an Alpine nappe stack telescoped by extensional detachment faulting (Kulidzhik area, Eastern Rhodopes, Bulgaria)", published in the International Journal of Earth Sciences (doi:10.1007/s00531-016-1293-4). In this comment, we would like to raise some scientific concerns relative to the data presented and exerted interpretations in the paper by Georgiev et al. (2016).

In their work, the authors proposed a model in which (1) the Kulidzhik nappe (Boyanov 1969) does not represent a Late Jurassic compressional thrust-related contact (Bonev et al. 2010a), but instead is a major Late Eocene Kulidzhik extensional detachment fault, with two secondary detachment faults beneath, and (2) the Rhodope nappes are somewhat telescoped in the Kulidzhik area by extensional detachment faulting. In this discussion, we reveal the field, chemical, sedimentary, structural and metamorphic data related to the Kulidzhik area in order to prevent the reader from any misleading tectonic proposal.

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Subdivision and composition

Georgiev et al. (2016) use the subdivision scheme for the metamorphic section in the Kulidzhik area into four lithologic and tectonic units from I to IV in ascending order, which they tie to previous subdivision scheme of Janák et al. (2011) that distinguishes four allochthons in a paper dealing with the eclogite facies metamorphism in the Western Rhodope region.

The Unit I, as described by the authors, is an orthogneiss unit including augen orthogneiss varieties that were already shown as high-grade basement orthogneiss unit at the base of the section in the Kulidzhik area (Bonev et al. 2010a, their Fig. 3a, b). The Unit IV consists of muscovite orthogneisses, but the sample Kul-6 studied by the authors for geochronology from Unit IV is described as muscovite orthogneiss consisting of K-feldspar forming augen. Bonev et al. (2010a) have shown the presence of augen orthogneisses in the Kulidzhik nappe allochthon (their Figs. 2, 3a) that is equivalent to the Unit IV of Georgiev et al. (2016). Thus, the Unit I appears lithologically similar to structurally uppermost Unit IV. Bonev et al. (2010a) compared the orthogneisses from the Unit IV with the orthogneisses from the footwall of the Byala reka extensional dome in the south of the region, and they found overlapping chemical compositions (Fig. 4d in Bonev et al. 2010a). This compositional

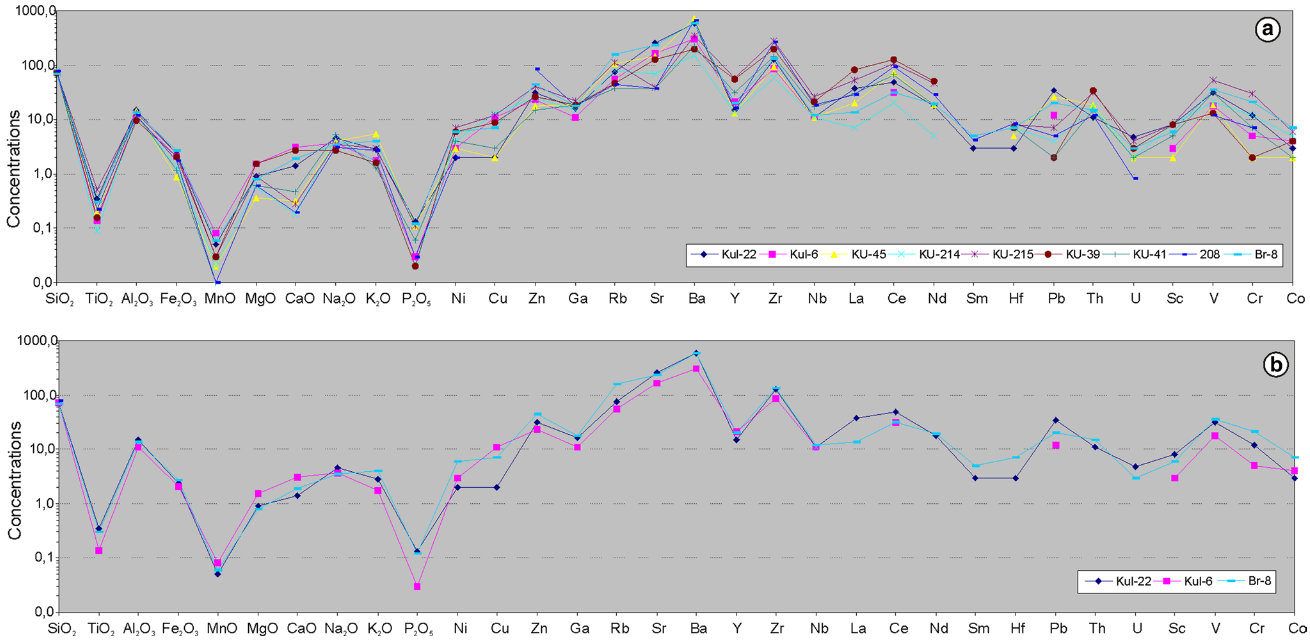

Fig. 1 Plots of chemical compositions of the orthogneisses in the Kulidzhik area. **a** Summary of the chemical data of the orthogneisses from the Units I and IV, including the data from Bonev (2006a) and Bonev et al. (2010a, b). **b** Chemical composition of orthogneiss samples Kul-22 of Carboniferous protolith age and orthogneiss sample Kul-6 of Neoproterozoic protolith age in Georgiev et al. (2016) and the Carboniferous 319 ± 9 Ma (Peytcheva and von Quadt (1995) augen orthogneiss sample Br-8 in Bonev et al. (2010b)

feature was put forward as an argument for the orthogneisses in the Kulidzhik nappe allochthon as belonging to the orthogneiss-dominated lower high-grade basement unit exposed in the footwall of the extensional core complex-type domes, where the augen orthogneisses have Carboniferous granitoid protolith ages (319–305 Ma, Peytcheva and von Quadt 1995). Figure 1a compares the orthogneiss samples from Unit I (Kul-22) and Unit IV (Kul-6) with the orthogneiss samples from the previous works [sample 208 in Bonev (2006a), five samples in Bonev et al. (2010a) and the sample Br-8 in Bonev et al. (2010b)], which comparison of the orthogneisses demonstrates again overlapping chemical compositions. Analogous to the augen orthogneiss sample Br-8, a sample of the same rock type and locality near the village of Siniger (I. Peytcheva pers. comm. 2009) was dated by U–Pb method on zircon at 319 ± 9 Ma (Peytcheva and von Quadt 1995). The compositional data of the orthogneisses from Unit I and Unit IV allow some caution to be expressed relative to the age of 581 Ma obtained for the Unit IV orthogneiss because of the comparable lithology and similar chemical compositions of the orthogneisses in the dataset. The orthogneiss dated at 302 Ma in the Unit I bears also xenocrystic zircon core of 567 Ma. It is probable that the age of 581 Ma in the Unit IV orthogneiss to be derived from the younger concordant but inherited zircons as the dated sample contains inherited 2.5 Ga to 700-Ma-old zircons. This stems also from the coincidence of the chemical composition of the sample dated at 581 Ma with the sample Br-8 whose equivalent orthogneiss is dated at 319 Ma (Fig. 1b). The attempt for correlation of the Unit IV orthogneiss with the Pirgadika unit orthogneiss assumed to overlie the Circum-Rhodope belt in the Chalkidiki Peninsula in Greece is incorrect. This is because not an orthogneiss from the Pirgadika unit (protoliths dated at 588 and 570 Ma), but a metaquartzite dated at 556 Ma assumed to belong to the Pirgadika unit was shown to lie on the Circum-Rhodope belt by Himmerkus et al. (2006) near the village of Taxiarchis in their Fig. 2. Therefore, there is no pre-Cambrian orthogneisses lying on the Circum-Rhodope belt in the Chalkidiki Peninsula.

The Unit II is described as predominantly consisting of garnet–chlorite–mica schist with subordinate amphibolite, marble layers and serpentinized ultramafic rocks. The map extent and the description of Unit II equals with the diaphthorized pre-Cambrian basement crystalline complex of Boyanov (1969). We disagree with the lithologic description of Unit II because of the discarded extent of the greenschist series as defined in Bonev et al. (2010a). Garnet-rich mica schists do occur at the base of Unit II (Bonev et al. 2010a, their Fig. 3c), but these garnet-rich mica schists are not present in the entire volume of this unit further up section till the contact with the Unit III. As the authors state, what is seen within the Unit II in the field are only the greenschists consisting of significant amount of chlorite and same grade metamorphic conditions of the deformation. Apart from the aforementioned rock

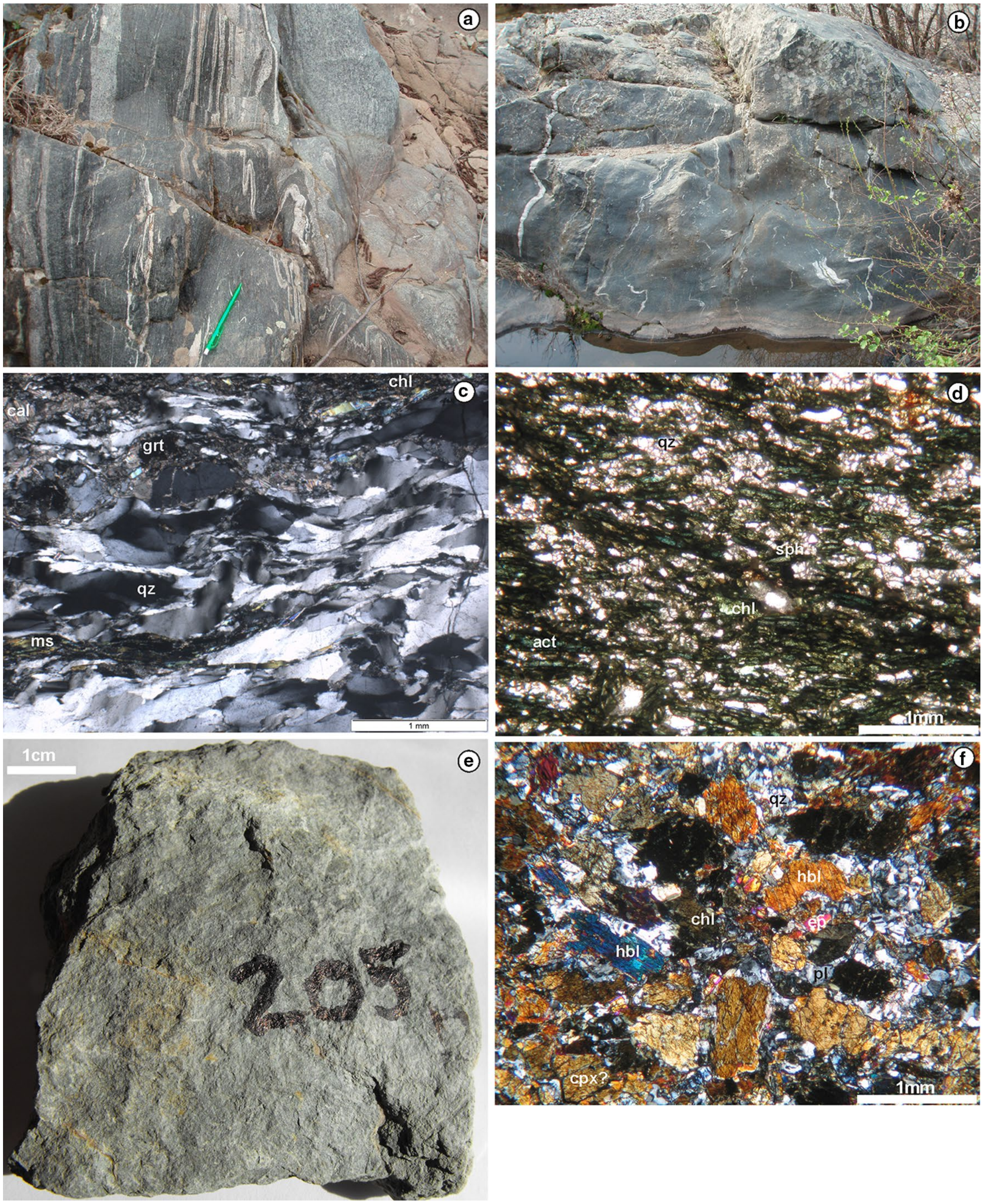

Fig. 2 Photographs of the field and microscopic aspects of the schists from the Unit II of Georgiev et al. (2016). The *photographs* represent lithologies of the Unit II in an ascending order from the base to the top in alphabetical order. **a** Folded garnet-rich mica schist (sample Ku-8-33 in Bonev et al. 2010a). **b** Folded greenschist (sample Ku-8-1 in Bonev et al. 2010a). **c** Quartz–white mica–chlorite–calcite–garnet schist structurally above the rocks depicted in **a** and **b**. Note detrital character of the quartz grains that show recrystallization under low-temperature conditions of deformation. **d** Quartz–actinolite–chlorite schist derived from mafic lava in the Unit II. **e** Sample of a greenschist derived from volcaniclastic (tuffaceous) rock from the Unit II. The sample number and the locality are shown in Bonev (2006a). **f** Micro-gabbro (dolerite) (sample Ku-159 in Bonev et al. 2010a) showing hornblende, quartz, plagioclase, epidote and chlorite. Note preserved primary igneous grain sizes and texture. *act* actinolite; *afs* alkali feldspar; *cal* calcite; *chl* chlorite; *cpx* clinopyroxene; *ep* epidote; *grt* garnet; *hbl* hornblende; *ms* muscovite; *pl* plagioclase; *qz* quartz; *sph* sphene (titanite); **c** and **f** crossed polarizers, **d** plane polarized light

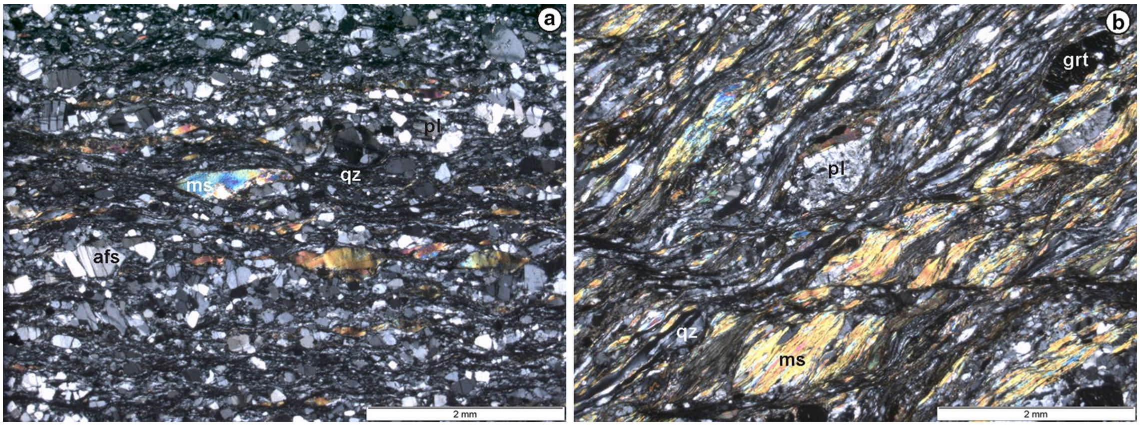

Fig. 3 Microphotographs (crossed polarizers) of the mylonites underlying the brittle detachment fault of the Byala reka dome. **a** Orthogneiss ductile–brittle mylonite. Note brittle behavior of the feldspar indicative of the temperature of deformation well below 450 °C and the new, localized low-temperature recrystallization of quartz in foliation-parallel bands. **b** Garnet-bearing mica schist intercalated with gneiss mylonite in **a**. Note the shear bands and same recrystallization of quartz in thin bands. Abbreviations are as mentioned in Fig. 2

type, quartz–white mica–chlorite–calcite–garnet schists of decreasing garnet content (Fig. 2c), quartz–actinolite–chlorite–sphene–Fe oxide schists (Fig. 2d), quartz–white mica–chlorite–epidote–calcite schists (Fig. 6 g in Bonev et al. 2010a) and other greenschist rock types are present in this unit. The cause of the difficulty for the authors in distinguishing the greenschists down section of Unit II and to assign the greenschists only to Unit III is that they stick to old presumption on diaphthoresis or retrogression of pre-Cambrian basement crystalline complex (Boyanov et al. 1969). The missing for the author's greenschists in the Unit II, however, were shown as derived from sedimentary rocks (Fig. 2a–c), island arc mafic volcaniclastic rocks (Fig. 2e), rare mafic lava flows (Fig. 2d; Bonev et al. 2010a, their Fig. 3d) and micro-gabbro (dolerite) (Fig. 2f) of IAT-MORB affinity that have experienced greenschist facies metamorphism and were also identified by their mineral and chemical compositions (Bonev 2006a; Bonev et al. 2010a).

Unfortunately, ignoring these mineral and chemical compositions, the authors do not show any convincing evidence for the existence of high-grade metamorphic rocks, namely higher than greenschist facies grade, such as the amphibolites, marbles and serpentinized ultramafic rocks they pretend for the Unit II, which then in turn were retrogressively overprinted under the greenschist facies metamorphic conditions.

The Unit III equates with the phyllite series of Boyanov (1969) and Bonev et al. (2010a). The Unit II and Unit III are considered as belonging to the Circum-Rhodope belt (Bonev 2006a) and not only Unit III as the authors erroneously state. The Unit III is inevitable from the subdivision because of the lithologic context of intercalated phyllites and recrystallized limestones that preserve primary sedimentary layering expressed by fine lamination (Bonev et al. 2010a, Fig. 3e), and thus, the Unit III displays a lower grade of the greenschist facies metamorphism compared to the underlying various types of greenschists or Unit II (Fig. 3).

Structure and metamorphism

Distinct foliations distinguished by the authors in the Units I–IV visibly are used to identify different phases of deformation, particularly for the Unit I and Unit II. However, from Fig. 5, it is quite obvious that all the linear and planar structural elements have same orientation in Units I–IV, and thus, no distinct deformation phases worth to be distinguished. Actually, the planar-linear elements depicted in Fig. 5 repeats the orientation of the structural pattern, as well as the kinematics already published in Bonev et al. (2010a). Conspicuous examples of overprinting foliations in Unit II ($S_{II\text{-}1}$, $S_{II\text{-}2}$ and $S_{II\text{-}3}$) are shown in Fig. 4b, c, f of Georgiev et al. (2016). In Fig. 4b what traces $S_{II\text{-}1}$ is a folded quartz layer with folds of thickened hinges and thin limbs whose trails outside the fold limbs are laterally continuous with the metamorphic layering labeled as the $S_{II\text{-}2}$ foliation, as well as also no fold closure associates when folded $S_{II\text{-}1}$. In the field, a single discernible and penetrative foliation represents metamorphic layering or schistosity structurally below (Fig. 2a) and above (Fig. 2b) relative to the outcrop depicted in Fig. 4b of Georgiev et al. (2016). No distinct foliations and fold generations are observed in the outcrops of Fig. 2a, b, but discontinuously folded single prominent metamorphic layering. In Fig. 4c, the $S_{II\text{-}2}$ foliation is traced by a quartz layer, while in contrast, the same

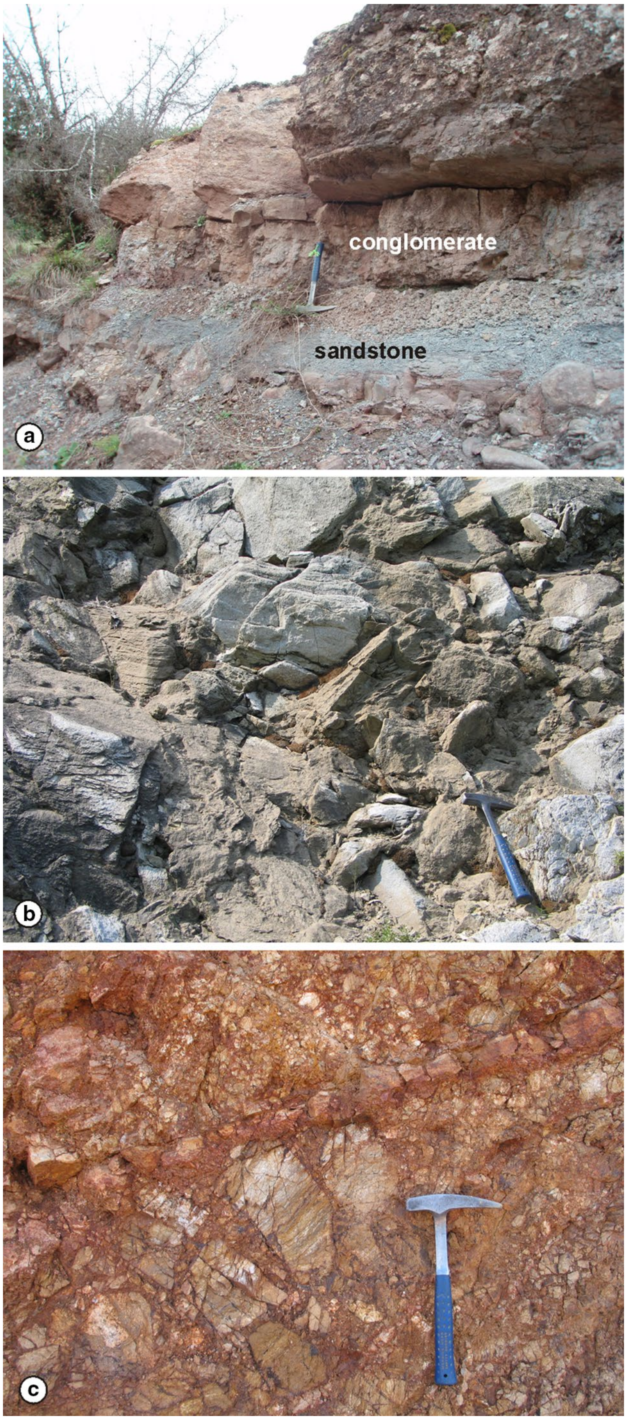

Fig. 4 **a** Upper Eocene conglomerates interstratified by sandstone beds unconformable overlying the Units IV, III and II in the Kulidzhik area. **b** Maastrichtian–Paleocene to Lower Eocene marble breccias almost without matrix overlying the detachment fault bordering the Kesebir dome. **c** Same as in **b** breccias consisting of paragneiss and amphibolite clasts with a minor matrix

foliation is traced by the garnets in Fig. 4f. The $S_{II\text{-}2}$ foliation is apparently defined freely by disseminated garnets that can define either $S_{II\text{-}2}$ or $S_{II\text{-}3}$ in both Fig. 4c, f. The foliation $S_{II\text{-}3}$ depicted in Fig. 4a is defined by metamorphic layering in a similar way as $S_{II\text{-}1}$ and $S_{II\text{-}2}$ foliations in Fig. 4b. However, whereas the location of the outcrop in Fig. 4a relative to the village Bryagovets is true, i.e., just west from the ultramafic body (conspicuous) on the map in Unit I, the outcrop in Fig. 4a is not from the uppermost section of Unit II as explained in the caption of Fig. 4a or close to the contact with the Unit III as written in the text. Nevertheless, the overprinting $S_0//S_1–S_2$ foliations were shown for the recrystallized limestones to marbles and the greenschists of the low-grade Mesozoic unit (Bonev et al. 2010a, their Fig. 12a; Bonev and Stampfli 2011), but the foliations described by the authors cannot be considered penetrative for the Unit II as they insist. Even being sensitive lithologies to preserve overprinting foliations, the phyllites of Unit III just below the Kulidzhik nappe contact do not show distinct foliations, despite strongly folded as the greenschists shown in Fig. 2a, b.

The contact between the Units II and III has not been shown as tectonic contact by previous authors (Boyanov 1969; Bonev 2006a; Sarov et al. 2008; Bonev et al. 2010a) who described the phyllite series recrystallized limestones and phyllites of Unit III as lithologically overlying the calc schists and chlorite schists of the greenschist series, Mandrica lithotectonic unit or Unit II. The greenschist sample 205b shown in Fig. 2e demonstrates the volcaniclastic lithologies of the greenschist series or Unit II that lie below the presumed tectonic contacts such as the Kulidzhik detachment fault and the underlying secondary detachment fault at vicinity to the village Meche uho. A weak foliation in this sample argues against any high strain intensity that can be expected close to presumed tectonic contact, and the weak deformation is only expressed by a weak schistosity defined by quartz–chlorite–mica aggregates. The undeformed micro-gabbro (Fig. 2f)-bearing hornblende (protolith depended)–quartz–plagioclase(protolith depended)–epidote–chlorite greenschist facies assemblage clearly preserves the primary igneous grain sizes and texture lying just below the phyllites and the recrystallized limestones of Unit III and the presumed secondary detachment below the inferred Kulidzhik detachment.

Although conspicuous in the field, the top-to-the-south structures of Unit I depicted in Fig. 6a–c of Georgiev et al. (2016) cannot be compared to the strain intensity and deformation mechanism of temperature well below 450 °C in the ductile–brittle mylonites of the shear zone below the brittle detachment in the Byala reka dome in the south as depicted here in Fig. 3. Moreover, no overprinting of the top-to-the-south by the top-to-the-north shear structures is clearly demonstrated for the Unit I, but this is instead used by the authors to infer separate tectonic displacements along the contact between the Unit I and Unit II, which contact in turn is poorly exposed, and the authors fairly know this from the field.

The authors insist on high-grade metamorphism of the Unit II reaching amphibolite to high-pressure granulite facies in the range of $T = 570–850$ °C and $P = 0.4–2.0$ GPa. $P–T$ estimate comes from Ti-in-zircon thermometry and phengite inclusions in a single zircon grain of the garnet–chlorite–mica schist sample Kul-21 dated at 150 Ma. This $P–T$ estimate and the age obtained are used for the assignment of the Unit II to the high-grade metamorphic basement, i.e., the upper allochthon equated with the Kimi unit and Krumovitsa unit. However, the garnet–chlorite–mica schist studied cannot be anyway compared to the lithologic context and metamorphic assemblage with the dated at 158 Ma garnet–kyanite gneiss (e.g., Figure 2 in Liati et al. 2016) intercalated with amphibolitized eclogites, spinel–garnet metaperidotites and garnet pyroxenites in the Kimi unit which has UHP, HP, HT and MP metamorphic history (Mposkos and Krohe 2006 and references therein; Krenn et al. 2010). The peak temperature estimate of 854 °C by Ti-in-zircon thermometry, as far as we know, is the first ever recorded in garnet–chlorite–mica schist in the Rhodope. The upper limit of temperature is even higher than the high-temperature granulite facies conditions of $T = 770–820$ °C and $P = 1.55–1.75$ GPa in eclogite and kyanite-bearing garnet mica schist of $T = 750–800$ °C and $P = 1.1–1.3$ GPa dated between 170 and 160 Ma in the Kimi unit (Bauer et al. 2007). This temperature is again higher than the high-pressure conditions of $T = 670–700$ °C (derived by Ti-in-zircon thermometry) and $P \sim 1.5$ GPa of dated at 158 Ma metamorphic zircon rim in the garnet–kyanite gneiss of the Kimi unit (Liati et al. 2016). The mineral assemblage in the schist sample Kul-21 is described consisting of quartz, garnet, white mica, biotite, plagioclase and chlorite. Bonev et al. (2010a) have shown the same matrix assemblage in these schists (samples Ku-8-33 (Fig. 2a) and Ku-8-1) of the Unit II very close to the sample Kul-21 locality, with mineral compositions of almandine garnet ($Prp_{10.1\text{-}3.6}$ $Alm_{61.7\text{-}57.3}$ $Sps_{17.5\text{-}8.4}$ $Adr_{8\text{-}2.3}$ $Uv_{0.2\text{-}0.04}$ $Grs_{18.3\text{-}14.3}$), muscovite, biotite and albite–oligoclase ($An_{11.3}$). In the same rock type, similar mineral compositions were also reported by Boyanov et al. (1969) for the Kulidzhik area. From the mineral compositions of the metamorphic assemblage in these garnet-bearing mica schists of the Unit II, it is very difficult to infer a metamorphic grade higher than greenschist facies having in mind the overlying rocks depicted in Fig. 2. The almandine garnet in our samples Ku-8-33 and Ku-8-1 is not comparable with the garnet composition $Prp_{38–33\,\%}$ in eclogite and $Prp_{36–23\,\%}$ in kyanite-bearing garnet mica schist (Bauer et al. 2007) and $Prp_{42.4–26.2\,\%}$ in metamafic rocks (Bonev et al. 2013a) of the Kimi unit. Therefore, the garnet–chlorite–mica schist sample Kul-21 and our greenschist samples cannot be compared to garnet–kyanite gneisses or schists of the Kimi unit that have a complex UHP-HP-HT-MP metamorphic history. Furthermore, the peak temperature estimate for sample Kul-21 of Georgiev et al. (2016) cannot be compared to $T = 620$ °C recorded by the kyanite and common eclogites and orthogneisses of Carboniferous granitoid protolith of the Kechros complex that underlies the Kimi unit in Greece (Mposkos et al. 2012) or Unit II of Georgiev et al. (2016).

The authors themselves found contradictory that dated at 74 and 68–69 Ma metamorphic zircons that give $T = 819$ °C and $P = 2.0$ GPa for the sample Kul-21. Again, such high-temperature granulite facies metamorphic conditions are reported for the first time in garnet–chlorite–mica schist of the Rhodope in mentioned temporal frame 74–68 Ma. We have to bear in mind that the Krumovitsa unit is covered unconformable by Maastrichtian–Paleocene up to Lower Eocene sedimentary rocks (Goranov and Atanasov 1992) or these sedimentary rocks occur in fault contact with an extensional detachment fault (Bonev et al. 2006). The 69-Ma-old Chuchuliga granite intruding the Krumovitsa unit has assimilated marbles from this unit and crystallized at depth of 18 km at $P = 0.6$ GPa (Marchev et al. 2006) adjacent to the Kulidzhik area. The $P–T$ estimate at 74 and 68–69 Ma is unrealistic, if the sample Kul-21 belongs to the Krumovitsa unit or the upper allochthon, implying the sample to occur within a unit that supplies clastic material for sedimentary rocks near the surface at that time or to resided in the same time at depth under the Chuchuliga granite experiencing a high-grade metamorphism around 68–69 Ma. The 80 Ma-lasting constant maximum high pressures of 2 GPa in the sample Kul-21 contradict with available data on metamorphic decompression path, cooling histories and radiometric age on the metamorphism of the Kimi and Krumovitsa units. Late cross-cutting pegmatites in the Kimi unit dated at 65 ± 1 Ma (see Mposkos and Krohe 2006) and 62 ± 2 Ma (see Liati et al. 2016) and $^{40}Ar/^{39}Ar$ amphibole age of 64.5 ± 4.3 Ma (Bonev et al. 2013b) in the Krumovitsa unit provide indisputable evidence that the amphibolite facies metamorphism had terminated by that time. In addition, the Late Cretaceous $P–T$ path of the sample Kul-21, suggesting the temporal frame of 80 Ma continuous peak pressures and temperatures, contradicts with the cooling history below 350 °C already in Late Jurassic ca. 155 Ma of the Kulidzhik nappe allochthon whose klippe rests a hundred meters up section above this sample.

Sedimentary constraints

The authors correctly state that the Upper Eocene sedimentary rocks unconformable overlie all metamorphic Units II–IV in accordance with the previous works (Boyanov

1969; Bonev 2006a; Sarov et al. 2008; Bonev et al. 2010a). The exception is Unit I which is covered by much younger Quaternary sedimentary rocks. Georgiev et al. (2016) correctly describe the Upper Eocene sedimentary rocks as rounded to variable degrees, unsorted clastic rocks that seal the detachment system, providing an upper age limit for this system. In the Kulidzhik area, the Upper Eocene sedimentary rocks are matrix-supported breccia–conglomerates and conglomerates interlayered with sandstone beds (Fig. 4a) that contain reworked clasts of the lithologies of the underlying metamorphic units. The Upper Eocene sedimentary rocks strata strikes from orthogonal to parallel relative to the map trace of the detachment system and dips at low angles mostly to the northwest and also to the southwest and rarely to the northeast (Bonev et al. 2010a, their Fig. 2), thus unsystematically away from the map trace of the inferred detachment system. The variable orientation of the Upper Eocene sedimentary strata demonstrates that they have been deposited onto already irregular relief which the sedimentary rocks fill. The Upper Eocene sedimentary rocks orientation stands in line with the statement of Boyanov (1969) about the existence of such relief and even earlier relief predating the Kulidzhik nappe emplacement. From Fig. 2 of Georgiev et al. (2016), it is clear that the Upper Eocene sedimentary rocks cover and seal the Kulidzhik detachment fault map trace, as well as both its hanging wall (Unit IV) and the footwall rocks (Unit III) and the secondary detachment that lies between the Unit II and Unit III. Such relationships reveal that the Upper Eocene sedimentary rocks postdate the tectonic contacts and metamorphism of the rocks in the Kulidzhik area, and in this way, they cannot be considered as syn-tectonic sediments related to the Kulidzhik detachment system assumed active between 45 and 33 Ma. Rounded conglomerate pebbles interstratified with sandstone beds argue for erosion and near surface very shallow water deposition (Fig. 4a) and against syn-tectonic sedimentation. The Upper Eocene sedimentary rocks in the Kulidzhik area therefore simply represent a post-tectonic unconformable sedimentary cover. As a reminder back to September 2006, when the principal author has shown the syn-tectonic Maastrichtian–Paleocene to Lower Eocene sedimentary rocks in fault contact with the detachment bordering to the north and the Kesebir dome to the southwest, these sedimentary rocks are additionally depicted in Fig. 4b, c. The clast-supported coarse blocky monomictic marble breccias almost without matrix in Fig. 4b and the amphibolite and paragneiss clasts-dominated breccias in Fig. 4c both reveal syn-tectonic hanging wall sedimentation by crushing of the hanging wall rocks and deposition on slopes bordered by high-angle faults (often mineralized) that sole into the low-angle detachment (e.g., Marchev et al. 2005). Therefore, we found missing the critical sedimentary constraint such as the syn-tectonic hanging wall sedimentation in support of the pretended Kulidzhik extensional detachment system.

Geochronology

The U–Pb geochronology in Georgiev et al. (2016) provides any constraints on the timing relevant for the processes linked to the extensional history of the Eastern Rhodope, namely the ages obtained by medium- to low-temperature $^{40}Ar/^{39}Ar$ geochronology that revealed footwall exhumation and cooling below 400–300 °C between 39 and 35.5 Ma in the extensional domes that overlap hanging wall hydrothermal mineralization at 280–180 °C between 37.6 and 34.7 Ma hosted by supra-detachment sedimentary rocks, and the hanging wall cooling below 500–300 °C in the range of 64–34 Ma (Moritz et al. 2010, 2014; Bonev et al. 2013b, and references therein). These thermochronologic constraints cannot be ignored as temporal guidelines when for the Kulidzhik area, Georgiev et al. (2016) put forward an extensional hypothesis with extensional detachments assumed active between 45 and 33 Ma. Nevertheless, the positive outcome from the U–Pb geochronology in Georgiev et al. (2016) is obtained protolith crystallization age of K-feldspar augen orthogneisses in Unit I that really represents the lower high-grade basement unit exposed in the footwall of the Eastern Rhodope extensional domes and the hint on the metamorphism in Late Jurassic time for the rocks of Unit II.

Tectonic evolution and the model

The authors insist on pervasive mylonitization with a top-to-the south shear sense in Unit I as the shearing described in Bonev et al. (2010b), where in Fig. 2b, it is shown a typical for the Byala reka dome orthogneisses top-to-the south shear related to the Rhodope Cretaceous ductile syn-metamorphic nappe stacking in amphibolite facies. The orthogneisses of Unit I around the village of Bryagovets have restricted areal extent, and the ductile top-to-the south shear sense is particularly conspicuous in the very limited outcrops of the orthogneisses. We have shown how it looks like the top-to-the south extension-related shearing in the ductile–brittle mylonites of the Byala reka dome in Fig. 3. The intensity of shear deformation, with preserved the top-to-the north large K-feldspar augens in the orthogneisses depicted in Bonev et al. (2010a, their Fig. 3b) and the top-to-the south in Fig. 6a–c and Fig. 3a depicted in Georgiev et al. (2016), is incomparable to the intensity and mechanism of deformation observed in the extension-related ductile–brittle mylonites in terms of the grain size reduction and the low temperature of the shear deformation. The contact of the orthogneisses of the Unit I with the Unit II was suggested as N-directed ductile thrust by

Bonev et al. (2010a) or S-directed then N-directed extensional detachment by Georgiev et al. (2016). What extensional detachment will be the pretended contact without exposed footwall, where Unit I is covered by Quaternary deposits in the Arda River and with a map trace less than one kilometer of the detachment west of Bryagovets, and this contact is questionable easterly of the village? We have mentioned above that the boundary between the Unit II and Unit III is a lithologic contact. The detachment fault arguments of the authors for this contact such as upward increase in mylonitization, chloritization, cataclastic overprint of the mylonites and the decrease in temperature are too weak to suggest an extensional detachment. Firstly, the rocks on both sides of the contact are chlorite rich because they are originally greenschists; secondly, the greenschists lay below phyllites and recrystallized limestones that preserve the primary sedimentary features testifying lower greenschists facies metamorphic grade; and thirdly, both are overthrusted by orthogneisses along the brittle surface of the Kulidzhik nappe. From the description of the authors that few tens or less meters above the contact of the Units II and III lie at the base of the Unit IV, the assumed Kulidzhik detachment that is conjugate structure to the contact of the Units II and III follows that we simply deal with the fault planes of the brittle tectonic zone of the Kulidzhik nappe. Thus, there is no need to infer another detachment between the Unit II and Unit III, which the latter unit is locally very thin.

In addition, solely a brittle tectonic zone, its main fault surface and related fault planes do not necessarily imply an extensional detachment. Together with the brittle deformation mechanism, there are many other important criteria for distinguishing the extensional detachments.

The hanging wall of the assumed Kulidzhik detachment had cooled below 350 °C in Late Jurassic time (ca.157–154 Ma) whose immediate footwall is built of black shales that yielded Lower Jurassic radiolarians (Tikhomirova et al. 1988) (late Pliensbachian to pre-Bajocian taxa, P. Baumgartner (Lausanne) pers. comm. 2003). Down section the footwall is built of greenschists that virtually extend into the base of Unit II (Fig. 2), where metamorphic event is recorded at 150 Ma which only lower *P–T* limit generally could be accepted with reserves. From the compositions and temporal frame in the tectonostratigraphy and the cross section in Fig. 3 of Georgiev et al. (2016), the structure of the Kulidzhik area simply appears as a greenschist unit thrust slice sandwiched between two orthogneissic basement units thrust slices, all having uniform structural pattern and showing a common N-directed tectonic transport direction in same greenschist facies metamorphic grade. The Kulidzhik nappe brittle surface inferred as the Kulidzhik detachment actually straddles Jurassic tectono-metamorphic and sedimentary history from the hanging wall to the footwall that confirms outlined above structure of the Kulidzhik area. It is therefore difficult to accept the development within the section of 300 meters of three inferred Late Eocene–Oligocene detachment faults, which detachments leave no Tertiary time-corresponding hanging wall brittle deformation and syn-tectonic sedimentation, and having same structural and metamorphic pattern in the mentioned thickness.

The model of the Eastern Rhodope extensional system adapted for the Kulidzhik area in Georgiev et al. (2016) starts in Late Eocene time. This inconsistent time frame of extension is significantly younger because we have already mentioned above the Early Eocene maximal age for the onset of extension as derived from the sedimentary constraints in the detachment hanging wall. Disregarding the sedimentary constraints and Late Eocene hydrothermal mineralization in the hanging wall sediments that have experienced brittle extensional deformation along high-angle faults, the authors introduce three extensional detachments without extension-constraining age information. Do the authors really believe that they can make and proof three detachments active between 45 and 33 Ma? We do not because our experience shows that the low-temperature cooling, extensional tectonic and hydrothermal processes encompassing a single detachment in each of the core complex-type domes of the Eastern Rhodope extensional system developed between 42 and 34 Ma (Bonev and Stampfli 2011; Bonev et al. 2013b). They built their three detachments model referring to all Rhodope detachments from the Kulidzhik area to the Chalkidiki Peninsula ignoring the asymmetric and symmetric mode of the syn- and post-orogenic Tertiary crustal extension per respective temporal frame as outlined by Bonev (2006b) and Bonev and Beccaletto (2007) for the Eastern Rhodope and adjacent areas.

Additionally, the authors exploited also the Rhodope ductile nappe stack outside the study area where the units in superposition are said to build Alpine nappes as appears in the title, but no evidence is provided that the Kulidzhik area units are involved in the nappe stacking. Just opposite, they discard the Kulidzhik nappe and speculate with the Rhodope nappe stack on which built the extensional hypothesis of pick up the Alpine nappes.

The only structures related to the crustal extension in the Kulidzhik area are high-angle faults that cross-cut the entire metamorphic section including also the Upper Eocene sedimentary rocks (e.g., Bonev et al. 2010a, their Fig. 15). These faults are late tectonic structures accommodating still ongoing brittle extension in the Oligocene time in the Eastern Rhodope of Bulgaria and Greece, as well as in the case at the northern tip of the Byala reka dome of the area in question.

Conclusions

We found some data discrepancies and misinterpretations in Georgiev et al. (2016) summarized in the following points.

1. The Unit I and Unit IV orthogneisses might well belong to the same unit in terms of the lithology and chemical compositions, despite the different age results obtained for them.
2. The correlation of Unit II with the Kimi unit and Krumovitsa unit or upper allochthon contradicts with the lithologic context of rock association and the metamorphic assemblages in the Kimi unit and Krumovitsa unit that records UHP-HP-HT-MP metamorphic history. Such history, lithologies and metamorphic assemblages are not recorded in the Unit II. Simple adjustment of the U–Pb ages obtained for the Unit II and adapting them to the coincident U–Pb ages available for the Kimi unit do not work for correlation purpose because the Kulidzhik greenschists contrast with the Kimi unit lithologies.
3. The pretended Kulidzhik detachment and the two secondary detachments in a metamorphic section reaching thickness of 300 m lack sedimentary constraints, structural support and time-integrated evidence that are known for the Tertiary Eastern Rhodope extensional system. Instead, the structure of the Kulidzhik area consists of north-directed nappe stack in greenschist facies involving crustal and arc-related ophiolite rocks that were thrust emplaced in Late Jurassic time as recorded in both the hanging wall and the footwall of the originally defined thrust stack.

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