Acta Geologica Polonica, Vol. 72 (2022), No. 1, pp. 141–144
DOI: 10.24425/agp.2021.139310

Reply to the "Discussion"

Oszczypko, N., Oszczypko-Clowes, M. and Olszewska, B. 2020. Geological setting and lithological inventory of the Czarna Woda conglomerates (Magura Nappe, Polish Outer Carpathians). *Acta Geologica Polonica*, **70**, 397–418.

NESTOR OSZCZYPKO[1], MARTA OSZCZYPKO-CLOWES[1,*] and BARBARA OLSZEWSKA[2]

[1] *Jagiellonian University, Institute of Geological Sciences, Gronostajowa 3a, 30-387 Kraków, Poland,*
[2] *Polish Geological Institute, Carpathian Branch, Skrzatów 1, 31-560 Kraków, Poland*
* *Corresponding author; e-mail: m.oszczypko-clowes@uj.edu.pl*

The authors are extremely grateful to Jurewicz (2022) for her insightful reviews of the two works, and are grateful to her for noticing the editorial and interpretational shortcomings, which escaped not only the attention of the authors, reviewers, but also the managing editors. The differences in the maps provided for the 2014 and 2020 papers are due to minor interpretational differences and will be corrected in the final version of the map that will be released soon.

It appears to the authors that Jurewicz (2022) does not really discuss the results of the articles, but rather questions the results of the micropalaeontological and cartographic research, which are, in fact, the basis for the authors' interpretation. Moreover, this is not the first time that the results of the research on coccoliths have been questioned. The paper written by Jurewicz and Segit (2018) considers that a sufficient argument to question the credibility of the age determination was the fact that "….Neither the data on sample abundance, preservation, species frequencies nor illustrations of the species were given…." Contrary to this claim, the index species are illustrated with photographs in Oszczypko and Oszczypko-Clowes (2014). However, one should not expect that all the species from each sample would be illustrated in individual microphotographs. Placing doubts next to the age of the coccoliths, Jurewicz and Sigit (2018) forget about the presence of *Sphenolitus disbelemnos*, index species for NN2, which is present in sample WP 385 (Czarna Woda). To help the reader, details of the sample abundance and nannofossil preservation were provided in the table, given in Appendix 2 (Oszczypko and Oszczypko-Clowes 2014) and explained in the text.

The Kremna Fm was defined by Oszczypko *et al.* (2005) as the youngest Oligocene–Lower Miocene member of the Magura Succession in the Peri-PKB zone. Calcareous nannoplankton studies of the Kremna Fm indicate a latest Oligocene /early Miocene age, i.e. specifically, NN1 and NN2 zones (Oszczypko *et al.* 2005) and these have been recognized and documented from several localities including:

– The Obrućne and Dubne localities (Muszyna area), in the Krynica facies zone, in front of the Pieniny Klippen Belt (PKB) (Oszczypko and Oszczypko-Clowes 2010).
– Nowy Targ–Krościenko area in the Krynica facies zone, in front of the PKB (Oszczypko *et al.* 2018)
– The Jaworki area (Oszczypko and Oszczypko-Clowes 2010, 2014).
– In tectonic windows through the PKB (Oszczypko and Oszczypko-Clowes 2010, 2014) ("Magura Autochthonous Paleogene" of Birkenmajer 1977).

Additionally, in three sections (Szlachtowa, Knurów and Waksmund) of the Kremna Fm., Early Miocene foraminifera have been recognized (Soták in Oszczypko *et al.* 2018). Oligocene–Lower Miocene flysch deposits, similar to Kremna Fm, have been documented also in:

– The Horná Orava region of Western Slovakia (Magura Nappe) (Oszczypko-Clowes *et al.* 2013).
– The Nowy Targ 1 borehole (Paul and Poprawa 1992), close to the northern boundary of the PKB (Magura succession).

– The peri-PKB zone near Humenné (Magura Nappe, Matašovsky and Andreyeva-Grigorovich 2002).
– The Podhale areas, between Stare Bystre and Rogoźnik villages (Stare Bystre formation, Kaczmarek *et al.* 2016).

The presence of Early Miocene deposits of the Kremna Fm in the Magura Nappe, in front of the PKB, as well as in the tectonic windows beneath the Grajcarek Unit and Klippen nappes , together with a lack of evidence for deposits of Early Miocene age in the Rača and Siary sub-units of the Magura Nape (Oszczypko-Clowes 2001), neither in the Grybów and Dukla units (Oszczypko and Oszczypko-Clowes 2004, 2011; Oszczypko-Clowes 2008), imply that the foreland basin (in front of the Outer Carpathian accretionary wedge) and the remnant (piggy-back) basin (in front of the PKB) were separated by the partially uplifted Outer Carpathians (Oszczypko and Oszczypko-Clowes 2009, 2014; Kováč *et al.* 2017, 2018).

The latest Oligocene–Early Miocene evolution of the eastern margin of the ALCAPA Mega-unit provides evidence both of transtension (see Márton and Fodor 1995; Nemčok *et al.* 2006; Kováč *et al.* 2017) and transpression (Ratschbacher *et al.* 1991; Nemčok and Nemčok 1994; Tischler *et al.* 2007). The compression perpendicular to the moving system caused not only the thrusts of the Outer Western Carpathian accretionary wedge nappes, but also triggered back-thrusts along the PKB (e.g., Nemčok *et al.* 1998; Sperner *et al.* 2002; Marko *et al.* 2005; Oszczypko *et al.* 2005; Márton *et al.* 2013; Plašienka and Soták 2015). At the turn of the Early Miocene, after the deposition of the Kremna Fm, the PKB tectonic units together with the Grajcarek Unit overthrust the folded and partially eroded Magura Nappe. Overlap of PKB over the Magura Nappe is also confirmed by data from deep wells which penetrated the youngest deposits of the Magura Succession beneath the PKB (e.g., Lubina-1 near Myjava, Hanušovce-1 in Eastern Slovakia and Svalava 1 and Drahovo-1 in the Ukrainian Carpathians – fide Leško *et al.* 1985). The transpression was associated there with shortening of the accretionary wedge, which developed differently in the west and east. The Rhenodanubian Flysch together with the nappes of the Northern Calcareous Alps were thrust over the platform margin (e.g., Wessely 1988, 1992), whereas the rear parts of the Outer Western Carpathian accretionary wedge were still in the location of the deep fore-arc basin (Cieszkowski 1992; Maťašovský and Andreyeva-Grigorovich 2002; Oszczypko and Oszczypko-Clowes 2010, 2014, 2020; Oszczypko-Clowes *et al.* 2014; Kaczmarek *et al.* 2016; Kováč *et al.* 2016, 2017).

Lateral extrusion of the Central Western Carpathians and the Northern Pannonian domain accompanied by counter clockwise rotations (e.g., Márton and Márton 1996; Márton *et al.* 1999, 2000) were directly caused by the closing of mobile zones which included the PKB and Outer Western Carpathian accretionary wedge (e.g., Marko *et al.* 1995; Froitzheim *et al.* 2008; Márton *et al.* 2013; Kováč *et al.* 2017, 2018). These processes were accompanied by strike-slip faulting (e.g., Kováč *et al.* 1989; Marko *et al.* 1990, 1991). During the course of the Middle Miocene overthrusting of the Outer Carpathian accretionary wedge, its internal shortening was hampered by the backstop at the boundary between the PKB and the Central Western Carpathians block. This caused a strong compression on the Central Carpathian/PKB boundary. Initially, it caused retrochariage and the formation of zones of overturned beds, observed along the northern boundary of the PKB and then was followed by lateral, probably convergent, strike-slip movements along the southern and northern boundaries of the PKB. At present, such zones are represented by accretionary wedges, sutures, and deeply rooted strike-slip fault zones (e.g., Schmid *et al.* 2008; Ustaszewski *et al.* 2008, 2010; Kováč *et al.* 2016, 2017, 2018; Golonka *et al.* 2018, 2019; Marzec *et al.* 2020).

This tectonic displacement dismembered the initial geometry of the PKB, and allowed the opening of tectonic windows and the development of its present-day flower structure. Similar was observed in the eastern part of the PKB in Slovakia where, according to Hrušecký *et al.* (2006), the boundary zone was reactivated several times during the Paleogene–Neogene in a transpressional and/or transtensional manner (see also Ratschbacher *et al.* 1991; Nemčok and Nemčok 1994; Nemčok *et al.* 1998, 2006; Kováč *et al.* 2017), forming the vertical flower structure of the PKB. According to Marko *et al.* (2017), the western segment of the PKB displays faults formed in a strike-slip regime during the early stages of its Neo-Alpine tectonic evolution.

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Manuscript submitted: 17th December 2021
Revised version accepted: 17th January 2022