Reply to the “Discussion”


NESTOR OSZCZYPKO1, MARTA OSZCZYPKO-CLOWES1,* 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 micropalaeo-ontological 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 Segit (2018) forget about the presence of Sphenolithus disbellemnos, 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)

Additionally, in three sections (Szlaachtowa, Knurows 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, Maťašovsky 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 Márton 1996; Márton et al. 1999, 2000) 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; Płaśienka 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-I near Myjava, Hanušovce-I in Eastern Slovakia and Svalava I and Drahovo-I 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.

REFERENCES

Birkenmajer, K. 1977. Jurassic and Cretaceous lithostratigraphic Units of the Pieniny Klippen Belt, Carpathians. Studia Geologica Polonica, 45, 1–158. [In Polish]


Marko, F., Kováč, M., Fodor, L. and Satovska, K. 1990. Deformations and kinematics of a Miocene shear zone in the northern part of the Little Carpathians (Buková Furrow, Hrabník Formation). Mineralia Slovaca, 22, 399–410. [In Slovak, with English summary]


Maťašovský, M. and Nemčok, J., 1994. Late Cretaceous deforma-
tion of the Pieniny Klippen Belt, West Carpathians. *Tectono-
physics*, 290, 137–167.

partitioning along the western margin of the Carpathians.
*Tectonophysics*, 292, 119–143.

Nemčok, M., Pogácsás, G and Pospíšil, L. 2006. Activity tim-
ing of the main tectonic systems in the Carpathian–Pan-
nonian region in relation to the roll-back destruction of the
lithosphere. In: Picha, F. and Golonka, J. (Eds), The
Carpathians and their foreland: geology and hydrocarbon
resources. *AAPG Memoir*, 84, 743–766.

Nemčok, M., Hók, J., Kováč, P., Marko, F., Coward, M.P.,
Madarás, I., Houghton, J.J. and Bezák, V. 1998. Tertiary
extension development and extension/compression inter-
play in the West Carpathian mountain belt. *Tectonophysics*,
290, 137–167.

Oszczypko, N. and Oszczypko-Clowes, M., 2009. Stages in the
Magura Basin: a case study of the Polish sector (Western

Oszczypko, N. and Oszczypko-Clowes, M. 2010. The Pale-
gene and Early Neogene stratigraphy of the Beskid Sądecki
Range and Lubovnianska Vrchovina (Magura Nappe, West-

Oszczypko, N. and Oszczypko-Clowes, M. 2014. Geological
structure and evolution of the Pieniny Klippen Belt to
the east of the Dunajec River – a new approach (Western
Outer Carpathians, Poland). *Geological Quarterly*, 58,
737–758.

Oszczypko, N. and Oszczypko-Clowes, M. 2017. Geological
Map of the Male Pieniny Mts. and adjoining part of the
Sądecki Ridge (Polish Outer Carpathians). “GEOPROFIL”
Sp. z o.o.; Kraków.

Oszczypko, N., Oszczypko-Clowes, M. and Olszewska, B.
2020. Geological setting and lithological inventory of the
Czarna Woda conglomerates (Magura Nappe, Polish Outer

Oszczypko, N., Oszczypko-Clowes, M., Golonka, J. and Marko,
F. 2005. Oligocene–Lower Miocene sequences of the Pien-
iny Klippen Belt and adjacent Magura Nappe between Jar-
abina and Poprad River (East Slovakia and South Poland):
their tectonic position and paleogeographical implications.

Oszczypko-Clowes, M. 2001. The nannofossil biostratigra-
phy of the youngest deposits of the Magura Nappe (East of the
Skawa river, Polish Flysch Carpathians). *Annales Societa-
tis Geologorum Poloniae*, 71, 1–88.

and age of the youngest deposits in the Mszana Dolna and
Schzáwa tectonic win dows (Magura Nappe, West ern Car-

Oszczypko-Clowes, M., Soták, J., Oszczypko, N. and Surka, J.
2013. Biostratigraphic revis ion of the Magura Unit in the
Horná Orava region (Slovakia): constraints for Oligomi-
cene formations. In: Broska, I. and Tomášových, A. (Eds),
International Conference GEEWEC 2013, Smolenice, Oc-
tute, Slovak Academy of Sciences; Bratislava.

Oszczypko-Clowes, M., Oszczypko, N., Piecuch, A., Soták, J.
and Boratyn, J. 2018. The Early Miocene residual flysch
basin at the front of the Central Western Carpathians and
its paleogeographic implications (Magura Nappe, Poland).

in the Peri-Pieniny Zone in light of the Nowy Targ PIG 1
borehole (in Polish with English summary). *Przegląd Geo-
logiczny*, 40, 404–409.

Plašienka, D. and Soták, J. 2015. Evolution of Upper Creta-
ceous–Paleogene synorogenic basins in the Pieniny Klip-
pen Belt and adjacent zones (Western Carpathians, Slo-
vakia): tectonic controls over a growing orogenic wedge.
*Annales Societatis Geologorum Poloniae*, 85, 43–76.

Lateral extrusion in the Eastern Alps, Part 2: Structural

Schmid, S.M., Bernoulli, D., Fügenschuh, B., Matenco, L.,
Schefer, S., Schuster, R., Tischler, M. and Ustaszewski, K.
2008. The Alpine–Carpathian–Dinarid orogenic system:
correlation and evolution of tectonic units. *Swiss Journal
of Geosciences*, 101, 139–183.

between subduction retreat and lateral extrusion: Tectonics

Tischler, M., Gröger, H.R., Fügenschuh, B. and Schmid, S.M.
2007. Miocene tectonics of the Maramures area (Northern
Romania): implications for the Mid-Hungarian fault zone.

Ustaszewski, K., Kounov, A., Schmid, S.M., Schaltegger, U.,
of the Adria-Europe plate boundary in the northern
Dinarides: from continent-continent collision to back-arc

Ustaszewski, K., Schmid, S.M., Fügenschuh, B., Tischler, M.,
Kissling, E. and Spakman, W. 2008. A map-view resto-
ration of the Alpine–Carpathian–Dinarid system for the
Early Miocene. *Swiss Journal of Geosciences*, 101 (Sup-
plement 1), 273–294.