Geological Quarterly, 2018, **62** (3): 751–754
DOI: http://dx.doi.org/10.7306/gq.1424

„Depositional setting of the Oligocene sequence of the Western Carpathians in the Polish Spisz region – a reinterpretation based on integrated palynofacies and sedimentological analyses" – Reply

Anna FILIPEK[1,] *, Anna WYSOCKA[1] and Marcin BARSKI[1]

[1] University of Warsaw, Faculty of Geology, Żwirki i Wigury 93, 02-089 Warszawa, Poland

Filipek, A., Wysocka, A., Barski, M., 2018. „Depositional setting of the Oligocene sequence of the Western Carpathians in the Polish Spisz region – a reinterpretation based on integrated palynofacies and sedimentological analyses" – Reply. Geological Quarterly, **62** (3): 751–754, doi: 10.7306/gq.1424

We would like to thank Przemysław Gedl for his attention in reading our work and for the discussion he initiated (Gedl, 2018). First of all, we would like to note that our reply will concentrate on substantial comments on the presented results or/and questionable interpretations.

GEOLOGICAL SETTING

The authors admit that the use of the term "basin" in a lithostratigraphic context was awkward. The mistake was due to the unobvious geological structure of the Podhale region. Mastella (1975) suggested that the Podhale flysch-like deposits at present form the Podhale Synclinorium, but numerous drillings show that the bedrock occurs at different depths, which indicates the presence of many faults and internal shears (Janočko and Jacko, 1998; Soták and Janočko, 2001; Małecka and Nowicki, 2002; Chowaniec, 2003, 2009). Therefore, the application of the term "Podhale Synclinorium" is controversial. That is why we have decided to replace it with the term "basin". Currently, in the geological literature, there is a problem with the correct application of this term in geological, geographical and litostratigraphic contexts. Especially that the Oligocene sediments, which are present in the Central Carpathian area, are also described as the Central Carpathian Paleogene Basin including the Podhale and Liptov basins. A misunderstanding of the basin/synclinorium issue occurs in a number of previous papers (e.g., Soták et al., 2001; Alexandrowicz and Rudzka, 2006; Day-Stirrat et al., 2008; Oszczypko et al., 2008; Ludwiniak, 2010; Starek et al., 2012; Alexandrowicz, 2013).

Detailed sedimentological studies (based on particular lithology and characteristic sedimentary structures) have not been carried out in the Kacwin area prior to the paper by Filipek et al. (2017). Although there are papers devoted to sedimentological issues, they were focused mainly either on palaeotransport directions (e.g., Marschalko and Radomski, 1960; Westwalewicz-Mogilska, 1986; Soták et al., 2001) or on general geological topics for the entire Podhale region with only a small amount of data coming from the Polish Spiš region (Radomski, 1958).

BIOSTRATIGRAPHY

The stratigraphic assignments of the samples are usually individual interpretations depending on widely accepted stratigraphic ranges of index species. Until a microfossils group is not well tied to a biostratigraphy based on orthostratigraphic fossil groups within calibrated outcrop sections, the ranges fluctuate through geological time (e.g., Köthe and Piesker, 2008). Therefore, the discussion about the age of deposits in question is still open in our opinion. Accordingly, the opinion that "the presented results are completely different from the previous biostratigraphic determinations" is a slight exaggeration.

However, we disagree that our age assignment is based only on "the co-occurrence of several species, although most of them have ranges far beyond the Oligocene (Williams and Bujak, 1985; Stover et al., 1996; Williams et al., 2004): *Caligodinium amiculum* (Paleocene–Early Miocene), *Spiniferites ramosus* (earliest Cretaceous–recent), *Deflandrea phosphoritica* (earliest Eocene–Early Miocene), *Hystrichokolpoma rigaudiae* (earliest Eocene–Pleistocene), *Spiniferites pseudofurcatus* (Late Paleocene–Late Miocene), *Thalassiphora pelagica* (Maastrichtian–Chattian), *Reticulatosphaera actinocoronata* (mid Priabonian–Pleistocene)", as suggested by Gedl (2018). In the chapter "Age determination" of our paper, we clearly consider the taxa with short ranges for the age justifications. In some cases, we also mention other taxa that are numerically significant in the samples; however, we do not use them for stratigraphic determinations.

The main controversy widely discussed by Gedl (2018) about the age determination is the stratigraphic range of *Wetzeliella articulata*, which limits the stratigraphic position of the succession in question to the Lower Rupelian. We actually admit that suitable discussion would have been provided if

* Corresponding author, e-mail: anniafilipek@gmail.com
Received: May 8, 2018; accepted: May 8, 2018; first published online: July 16, 2018

stratigraphic issues were the main aim of the contribution. Finally, we have accepted the stratigraphic range of this species presented in the comprehensive contributions by Powel (1992) and Costa and Downie (1976) based on outcrop samples from England, neglecting a few reports concerning mainly borehole material.

The reason for omitting *Chiropteridium lobospinosum* occurring in the Lower Zakopane Beds (samples 648 and 414a) in the stratigraphic analysis was due to the poor preservation and low abundance of the recovered specimens. We agree that its position in the range chart should be marked by a question mark. However, the stratigraphic position of this species is not clear. Powel (1992) shows its first appearance within the upper part of the Rupelian, which evidently excludes its co-occurrence with *Wetzeliella articulata* (e.g., sample 414a). The co-occurrence of both species was already observed by Gedl (2000). This co-occurrence would probably be explained nowadays by Williams et al. (2004), who postulate the FAD of the taxonomically related *Chiropteridium galea* slightly above the base of the Rupelian.

Summarizing the biostratigraphical part of the paper, we appreciate that, after more than a decade and by studying a different set of samples, we have recovered assemblages resembling those distinguished by Gedl (2000). The final age interpretation will be possible after more intense future studies of the regional stratigraphic distribution of index dinoflagellate cyst taxa in the area. However, we are afraid that the omnipresence of flysch-type deposits will not support this challenge.

REDEPOSITION

Indeed, in our paper we use the terms “redeposition” and “recycling” as synonyms. There are two reasons for this: firstly, the paper deals mainly with flysch-type sedimentary processes, and secondly, we use the term “redeposition” in a wider sense. In our opinion, redeposition processes, by simultaneous acts of erosion, include either recycling or reworking. In palaeontological literature, recycling is more oftenas the presence of older fossils in younger strata with evidently discordant stratigraphic ranges in comparison to the bulk stratigraphic record. However, as is the case with microfossils, the specimens are rather relocated from older strata by resedimentation (redeposition) of small rock particles.

Gedl (2018) suggested that Filipek et al. (2017) incorrectly used the *Deflandrea* group to interpret the palaeoenvironment due to the presence of representatives of the same species (*Deflandrea phosporitica*) with a different state of preservation in one sample, which is related to the redeposition/recycling of specimens of this taxon: “…they reconstruct sedimentary setting of these deposits (Filipek et al., 2017: p. 864) without noting that a few pages away they treat them as recycled, and announce their omitting from further interpretation”. In fact, following Gedl (2000: p. 78, 151), we use group comprising *Deflandrea* and *Caligodinium* to support the reconstruction of the sedimentary setting. We have deliberately ignored the quantitative ratios between these taxa within the group due to redeposition/recycling, only highlighting this problem for further studies. Numerous specimens of *Caligodinium amiculum*, *Caligodium* sp. B and *Caligodinium* sp. have been found in the analysed samples, especially in sample 8Łm (Filipek et al., 2017). Specimens of *Caligodinium* spp. show similar preservation states. Furthermore, examination in UV light indicates that each representative of *Caligodinium* is characterized by bright fluorescence, which proves that the specimens were not reworked and can be used for palaeoenvironmental reconstructions. Finally, we conclude that three groups of cysts (*Wetzelliela*, *Deflandrea-Caligodinium* and *Spiniferites*) dominate within the dinoflagellate cyst assemblages. The large number of individuals within these groups points to deposition in the coastal part of the basin, near a river mouth or in an upwelling zone. According to the environmental model of Pross and Brinkhuis (2005), most taxa described in our study occur within shelf areas, including high-productivity sea surface zones.

SEDIMENTATION RATE

In our work (Filipek et al., 2017) we have estimated the sedimentation rate for the Podhale flysch-sequence (excluding the Upper Chochołów Beds) based on the geological time scale by Vandenbergh et al. (2012), in which the duration of the Rupelian is 5.8 My. Figure 3 from Filipek et al. (2017) shows that the co-occurrence interval of *Wetzeliella articulata* and *W. gochti* lasted ~2 My (based on Powell, 1992). Furthermore, Watycha (1976) calculated that the Podhale flysch-sequence (excluding the Upper Chochołów Beds) reaches a thickness of even 3000 m.

This is why the approximate sedimentation rate of the Central Carpathian Paleogene sequence in the Kacwin area reaches a minimum of 1.6 mm/y (Filipek et al., 2017). In the Szaflary and Zakopane beds, characterized by mud-rich accumulation, the sedimentation rate could be even higher if compaction is considered. For example, Barski and Bojanowski (2010) and Barski (2014) estimated ~60% compaction for the Krosno shales that are possibly a lithological equivalent of the upper part of the Podhale flysch-sequence. In contrast, in the Lower Chochołów Beds, dominated by sand-rich deposits, compaction may be neglected. We admit that the paper by Filipek et al. (2017) provides the minimum value.

PALAEOBATHYMETRY AND HUMMOCKY CROSS-STRATIFICATION

Sedimentological deduction should be supported by geological facts such as sedimentary structures combined with petrographic, geochemical, palaeoecological, taphonomic, and biostratigraphic data. In our paper, we have based our conclusions on integrated palynofacies and sedimentological evidences. Besides detailed palynological studies, we have described all sedimentary structures observed in the studied sections. Special attention was paid to structures indicative of the sedimentary environment, such as wave ripples (Filipek et al., 2017: fig. 10C), climbing ripples (Filipek et al., 2017: fig. 10D) and hummocky cross-stratification (Filipek et al., 2017: fig. 10G, H). These structures are treated as typical evidence of shallow-water environments and as indicators of sedimentation linked with both the oscillation of the wave-base location (e.g., Reineck and Singh, 1973; Nichols, 2001) and the physical properties of the flow (Tinterri, 2011). Such environmental interpretations are contrary to the common model of the palaeobathymetry of the Carpathian basins (e.g., Książkiewicz, 1977; Unrug, 1979; Gedl, 2000; Oszczypko et al., 2006; Cieszkowski et al., 2009). Traditionally, the Oligocene sequence of the CCPB was interpreted as deposited in a deep-marine turbidite setting (for references see Filipek et al., 2017). Hence, our interpretation combined with the traditional concept was obviously confusing. Therefore, we have decided to propose a new interpretation of the sedimentary environment during deposition in the CCPB.

It is not clear for us why our interpretation of the hummocky cross-stratification is controversial for our adversary. Hummocky cross-stratification or hummocky-type structures can be found in a wide variety of deposits typical of different environments such as fluvial (e.g., Browne and Plint, 1994), river-delta (e.g., Plint and Norris, 1991), fan-delta (e.g., DeCelles and Cavazza, 1992), shoreface-offshore (e.g., Walker et al., 1983; Aigner, 1985), turbidite (e.g., Mulder et al., 2009; Tinterri and Muzzi Magalhaes, 2011) and even pyroclastic deposits (Branney and Kokelaar, 2002). Moreover, a variety of flow mechanisms caused by oscillatory, unidirectional or combined flows are related to the oscillation of the wave-base location of the surface or even internal waves (e.g., Myrow et al., 2002; Dumas and Arnott, 2006; Pomar et al., 2012). Therefore, in each geological situation, the interpretation of the HCS should be performed carefully and combined with other sedimentological, palaeoecological and/or taphonomic records.

We would like to draw attention to our statements that “structures typical for turbidity currents and those typical for relatively shallow-marine deposits (HCS, wave ripples) coexist in the studied section”, “the abundant cuticle confirms a short distance from the source area”, and, moreover, the dinoflagellate cyst assemblages of *Wetzelliela* and *Deflandrea-Caligodinium* point to deposition in the coastal environment (Filipek et al., 2017). Therefore, based on all these records, we have proposed a new interpretation of the depth of the sedimentary environment of the studied clastic sequence that filled the CCPB during the Oligocene. The quiet, low-energy, relatively shallow-water (below the wave base of average storms) sedimentation, in which the clayey background deposition took place, was interrupted by high-energy storm events that caused wave-modified turbidites. This interpretation seems to be more likely. However, such statement needs further intense sedimentological investigations.

We would like to thank Przemysław Gedl for his valuable comments. Further studies in the discussed area are required to supplement the existing results and to verify them. This is particularly important in establishing relationships between the Central Carpathian Paleogene Basin and the Outer Carpathians, and in reconstructing the basin/basins architecture of the Carpathian region in the Oligocene.

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