Are we still far from a reliable solution? Comment on "Structural position of the Upper Cretaceous sediments in the Považský Inovec Mts. (Western Carpathians)"

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Abstract: The protracting debate about the position and tectonic affiliation of the Upper Jurassic to Upper Cretaceous sediments occurring in the Považský Inovec Mts has got a revived impulse by a new interpretation presented in the recent paper of Pelech et al. (2016). We discuss several aspects of their alternative explanation which considers the wedge-top position of Upper Cretaceous strata overlying the Tatric substratum, with Upper Jurassic and Lower Cretaceous rocks occurring as olistoliths. In particular, we question the inferred transgressive character of the Upper Cretaceous clastic deposits and the olistolithic nature of Upper Jurassic radiolarites, as well as we emphasize the metamorphic imprint and related deformation structures recorded in rocks under consideration.

Keywords: Western Carpathians, Považský Inovec Mts, Tatricum, Vahicum, Belice Unit

1. INTRODUCTION

Starting from the fundamental paper by Kullmanová & Gašpariková (1982), who documented the Late Cretaceous age of clastic sediments imbricated with the Tatric basement complexes in the northern part of the Považský Inovec Mts (Selec Block), the structural position of these sediments has become one of the most discussed issues of the Western Carpathian geology. The reason is obvious, since the Upper Cretaceous (Senonian) deposits should comply with one of three principal tectonic settings in the Western Carpathians: (*i*) synorogenic "wildflysch" formations terminating the sedimentary successions of several units in the Pieniny Klippen Belt (PKB), such as the Jarmuta Fm. of the Subpieniny (Czorsztyn) Unit, the Snežnica-Sromowce Fm. of the Pieniny (Kysuca) Unit, Hoštiná Succession of the Klape Unit, or Podmanín Succession of the Manín Unit; (*ii*) the latter two successions were later reinterpreted as the wedge-top, Gosau-type deposits overstepping the pre-Senonian strata of the Klape (Salaj, 2006) and Manín units (Plašienka, 1995[a]; Plašienka & Soták, 2015); (*iii*) post-emplacement transgressive sediments of the Gosau Supergroup covering the highest nappe units of the outermost Carpathian zones (Brezová Group over the Hronic nappes), or covering the Silicic nappes in more inner areas. The problem is that position of the sediments under question does not correspond to any of these three tectonic settings.

After detailed field and laboratory studies in 1990-ties, Plašienka and his co-authors (for the review see Plašienka, 2012) developed an unconventional idea considering that Upper Jurassic to Upper Cretaceous sediments of the Selec Block represent an independent tectonic unit (Belice Unit), which is characterized by a unique, presumably oceanic lithostratigraphic succession, and by a tectonic position below the overriding Tatric basement-cover thrust sheet. Relying on this, they affiliated the Belice Unit with the Carpathians prolongation the Southern Penninic (Ligurian-Piemont) oceanic tract into the Western Carpathian area – the Vahicum (term introduced by Maheľ, 1981). This novel, although controversial concept has aroused much attention and debate, but not a general acceptance.

2. DISCUSSION

In principle, the "Vahic model" is based on the following observations and arguments: a) although strongly dismembered, the lithostratigraphy of the Upper Jurassic to Cretaceous succession of the Belice Unit is exceptional, not comparable to any other in the Carpathians; b) on the other hand, the evolutionary trend of the Belice Succession from the Upper Jurassic to Lower Cretaceous deep-water pelagites to Upper Cretaceous synorogenic clastics is akin to sedimentary sequences characteristic for the Southern Penninic, presumably oceanic realms; c) rocks of the Belice Unit occur in separated slivers that are in tectonic contacts with surrounding Tatric basement complexes, less frequently with Permian cover sediments, i.e. never in a continuous succession with the Tatric sedimentary cover; d) since Senonian deposits are nowhere present in the Tatric domain as overlying its basement and/or cover complexes, they should represent an element structurally underlying the Tatric basement, which is in line with their deformational and metamorphic overprint. In a slightly modified form, this view was followed by Putiš et al. (2006, 2008) with the exception that these authors presumed an original palaeogeographic position of the Belice Unit on a

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distal Tatric passive continental margin, later overridden by the (Infra)Tatric Inovec basement Nappe and the "true" Tatric Panská Javorina basement Nappe. Principal differences in Alpine structural and metamorphic characteristics between the Inovec and Panská Javorina nappes were reported already earlier (Putiš, 1983, 1986, 1992).

In the discussed paper, Pelech et al. (2016) propose an alternative "wedge-top model", which in part expands a view presented already by Rakús & Hók (2005). In their opinion, the sediments under question are exclusively of Late Cretaceous age (Horné Belice Group) and represent synorogenic deposits resting directly on the Tatric basement and cover complexes. Subsequently, they were involved in post-Cretaceous deformation processes, including overthrusting by the Fatric and Hronic nappes. However, there are several aspects of this conception that are not consistent with the observed phenomena. In particular, we would like to discuss the following problematic issues: the inferred transgressive character of Senonian clastic deposits, the position and provenance of Upper Jurassic radiolarites, and the metamorphic conditions recorded in rocks of the Belice Unit.

Pelech et al. (2016) assume a transgressive character of the Horné Belice Group deposited in synorogenic, compressional wedge-top basins above the Tatric basement and cover complexes (their fig. 13). However, the transgression has not been documented anywhere and is highly improbable. In general, transgressive facies are characterized by coarse-grained, shallow-marine deposits with well-sorted and well-rounded pebbles composed mostly of local material. According to Marschalko (in Plašienka et al., 1994), both the Coniacian Čierny vrch polymict conglomerates of the "grey flysch" and breccias dominated by the micaschist clasts of the Campanian–Maastrichtian Hranty Beds ("red flysch") represent channelized deep-marine mass flows. The Čierny vrch conglomerates were inserted within turbiditic sequences in middle parts of turbiditic fans of bathyal submarine deltas. Olistoliths-bearing disordered breccias of the Hranty Beds originated as land debrites, transported down-slope as hyperconcentrated debris flows and finally were laid down at the slope hinge in bathyal depths, as it is revealed by ichnofossils and associated turbidites. Marschalko (*l.c.*) considered a trench-like setting for turbidites and breccias of the Hranty Beds. On the other hand, Pelech et al. (2016) do not provide new sedimentological studies of these sediments; thus the idea about their transgressive character is not supported by any relevant data. Moreover, they show the contacts of Upper Cretaceous sediments with the underlying and overlying Tatric complexes as systematically tectonic (their figs. 6 and 7).

The Upper Jurassic radiolarites have been regarded as a member of the Lazy Formation (Plašienka et al., 1994) continuing into Lower Cretaceous dark siliceous shales. Based on poorly preserved radiolarian fauna, the maximum possible time span of deposition of red ribbon radiolarites was first estimated to the Late Oxfordian – Early Berriasian (Peterčáková in Plašienka et al., 1994). The radiolarian assemblage was later re-evaluated by Goričan (cited by Rakús in Ivanička & Kohút (Eds.), 2011) and ranged to the Late Oxfordian – Kimmeridgian, possibly up to Early Tithonian. A similar time span was proposed by Plašienka & Ožvoldová (1996). Red radiolarites are passing into greenish silicites with scarce Tithonian radiolarians and with rare thin intercalations of biancône-type limestones with *Calpionella alpina* (Soták in Plašienka et al., 1994). On the Lazy profile, the sedimentation continued by fossil-free, dark grey siliceous pelagic shales. They contain very rare sections of hedbergelids pointing to up to Albian age of the upper? part of siliceous shales. Even though possibly also tectonically reduced, the Lazy Fm. on profiles Belice and Lazy (studied and described by Plašienka et al., 1994) represent a strongly condensed, Upper Jurassic – Lower Cretaceous sequence of abyssal pelagic sediments deposited entirely bellow the calcite compensation depth (CCD).

Whether or not was the Lazy Fm. underlain by an oceanic crust originally, remains an open question. Nevertheless, we can provide several positive arguments, as well as we list some disagreements with the olistolithic nature of radiolarites and other sediments of the Lazy Fm. assumed by Pelech et al. (2016):

We still suppose that, although imbricated, the Upper Jurassic – Cretaceous Belice Succession is generally continuous. The Lazy Fm. is dominated by calcite-free eupelagic sediments that have no analogues in other Western Carpathians successions, equally as the Horné Belice Fm. of Upper Cretaceous sequences of deep-marine clastics with specific composition and depositional settings. On the other hand, similar deposits are characteristic for the Upper Penninic units in the Western Alps and Apennines (see Plašienka, 1995[b]). The succession of Upper Jurassic radiolarites – Calpionella and Aptychus limestones – Lower Cretaceous pelagic shales, marls and limestones – Upper Cretaceous flysch is considered as indicative for units derived from the Ligurian-Piemont oceanic bottom, notwithstanding if they are still bounded to underlying ophiolites or detached (*e.g.*, Froitzheim & Manatschal, 1996; Stampfli et al., 1998; Schmid et al., 2004; Marroni & Pandolfi, 2007; Mohn et al., 2010).

Lithology and geochemistry of radiolarian cherts of the Lazy Fm. were studied in detail by Méres & Plašienka (2009, 2013), who documented that radiolarites are formed by red pelagic shales alternating with tiny laminae of radiolarian ooze and pigmented by primary Fe-Mn oxi-hydroxides. Geochemical proxies of red shales indicate their derivation from submarine weathering products of a mafic protolith, presumably oceanic crust magmatites. Accordingly, these are "true" abyssal, totally calcite-free radiolarites deposited entirely below the CCD level, likely in proximity of an active oceanic spreading centre and reworked by bottom currents. Pelech et al. (2016) mention this result, but do not offer an alternative explanation. They only accentuate that radiolarites themselves are not a reliable indicator of deposition on the oceanic crust, since Upper Jurassic radiolarites (mostly calcareous, however) are known also in areas built by continental crust. This is certainly true; radiolarites or radiolarian limestones are inserted within some other Carpathian deep-water Jurassic successions underlain also by Triassic platform carbonates (*e.g.,* the Ždiar Fm. of the Fatric Zliechov Succession – *cf.* Polák & Ondrejičková, 1993; Polák et al., 1998). In contrast, the Lazy radiolarites are unique by their total lack of carbonate content, by the association with red pelagic shales, by the absence of a stratigraphic underlier and by their stratigraphic range reaching possibly up to the Tithonian, because other Carpathian radiolarite formations are usually of the Callovian – Oxfordian age, seldom reaching Kimmeridgian.

The potential olistolithic nature of the radiolarites is suppressed by the following facts – the Lazy Fm. forms comparatively thin (a few tens of metres), but lengthy bodies laterally persistent for several hundred metres (for example the strip Horné Belice–Čierny vrch–Blatina continuous for ca 1.5 km, or 500 m long lens on the northern slopes of Humienec Hill), which would be improbable for internally weak brittle slide blocks. Moreover, no clasts of radiolarites have been found in Upper Cretaceous conglomerates or breccias. Instead, olistoliths and smaller blocks are composed of various basement and cover rocks, whereas Jurassic and Lower Cretaceous fragments are only represented by relatively shallow-marine facies like sandy-crinoidal, nodular and brecciated limestones (so-called Humienec succession). Therefore the provenance of radiolarites as possible olistoliths would remain unidentified. Interestingly, blocks in coarse-grained sediments of the Horné Belice Fm. show a various degree of the mid-Cretaceous low- to very low-grade metamorphic overprint (Putiš et al., 2008, 2009; Putiš & Tomek, 2016), which indicates their derivation from various levels of the Tatric thrust stack in the source area, *i.e.* thrusting-related exhumation processes.

Pelech et al. (2016) do not thoroughly discuss another principal feature of rocks of the Belice Unit – their metamorphic alteration. They only claim that the lack of HP/LT metamorphism speaks against the oceanic character of the Belice Unit. However, this was in fact documented. Despite the metamorphic transformation reached only higher diagenetic or anchimetamorphic conditions, not exceeding ca 250°C, it is well expressed in the rock fabrics. According to Putiš et al. (2008), composition of newly-formed phengitic micas in shales of the Belice Unit indicate metamorphic temperatures of ca 200°C and pressures of up to 600 MPa indicating burial depths of more than 20 km. These values indicate P-T conditions of the incipient HP/LT metamorphism, best explainable by position of the Belice Unit at the sole of an accretionary wedge or in upper parts of the subduction channel overridden by crustal-scale Infratatric and Tatric basement nappes. By no means can these conditions be reached only by involvement of Upper Cretaceous sediments into relatively shallow synforms and/or by loading by the Fatric and Hronic nappes (Pelech et al., 2016, fig. 13), since their cumulative thickness could hardly exceed 6–8 km. Equally important is the inverted metamorphic zonation, whereby the mylonites from soles of the overlying basement thrust sheets record higher temperatures and lower pressures (ca 300°C, 500 MPa – Putiš et al., 2008) compared to rocks of the Belice Unit. The resulting "hotter on colder" temperature distribution and downward pressure increase is then particularly characteristic for the thick-skinned overthrust terrains.

Summing up, it is obvious that the present state of research of the Upper Cretaceous rocks in the Považský Inovec Mts does not allow for an exact solution of their tectonic position with respect to the general structure of zones at the Central Western Carpathians – Pieniny Klippen Belt interface. The concept of Pelech et al. (2016) offers a comparatively simple explanation which, however, is not in line with several fundamental data from the area. In particular, we have emphasized: a) the deep-marine depositional settings of Upper Cretaceous conglomerates, which are inconsistent with the transgressive wedge-top position; b) the special lithological-geochemical character of the Upper Jurassic radiolarites indicating their really oceanic origin; c) the improbability of their occurrence as olistoliths; d) the signs of incipient HP/LT metamorphism that rule out the shallow structural position of the discussed rock complexes implied by the piggyback, wedge-top model proposed by Pelech et al. (2016). On the other hand, we have to consent to several arguments of Pelech et al. (2016), especially concerning the absence of oceanic basement rocks as possible substratum of the Belice Unit (see also Putiš et al., 2008). Nevertheless, the subduction-related accretionary wedges might not include the ophiolitic material at all, provided that effective detachment horizons facilitate complete disconnection of accreted oceanic sediments from their subducting substratum.

3. CONCLUSIONS

In conclusion, we would like to note that simplistic models, such as that presented by Pelech et al. (2016), might be attractive, but also misleading. This is particularly true if the new ideas are based on arbitrarily chosen facts overlooking the general context, or if they only reinterpret results of previous research without presenting new sound data. Although some observations presented by Pelech et al. (2016), for instance the mesoscopic structural measurements and their interpretation (essentially the same as documented by Plašienka, 1995[b], 1999; Putiš et al., 2006, 2008), can be accepted without problems, the general tectonic interpretation goes far beyond these data and stays on a shaky ground.

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