Mesozoic paleogeography and facies of the Northern Mediterranean Tethys from the West Carpathian view

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Abstract
West Carpathian Mesozoic paleogeographic development indicates effect of a left lateral shift of the Alpine-Carpathian microcontinent along the European shelf since the Early Jurassic. The evolution during Late Triassic/Early Jurassic was controlled by convergence along border of the Meliata Ocean and by contemporaneous divergence along the Middle Atlantic/Penninic rift. During Mid Cretaceous, the convergence between Africa and Paleoeurope started, which finally resulted in collision of Alpine-West Carpathian microcontinent with Paleoeuropean margin and in the formation of the Alpine nappe pile.

Key words: *Mesozoic, Mediterranean Tethys, lithofacies, paleogeography, Western Carpathians*

1.Introduction
The North Alpine- and West Carpathian Mesozoic sequences were deposited on fragmented remnants of Variscan consolidated North European shelf crust. In Triassic times, the Outer Carpathian domain belonged to the southern Palaeoeuropean shelf segment adjacent to the eastern European border between the Bohemian Massif and the Ukrainian Shield. The Triassic sedimentary record in this area is mostly unknown (this area was mostly emerged, local deposits were eroded, covered or tectonically fragmented during later evolution, cf. Michalík in Feist-Burkhardt et al., 2008).In contrary, the central West Carpathian block together with the Eastern Alpine fundament was part of an independent microcontinent. This terrain was attached to another part of the Palaeoeuropean margin between the Bohemian and the Armorican Massifs and bordered to its southern side by the Meliata Ocean. The Triassic sequence of this area consists of several sedimentary megacycles deposited under changing climatic, eustatic and palaeoceanographic conditions in the Western (Mediterranean) Tethys.
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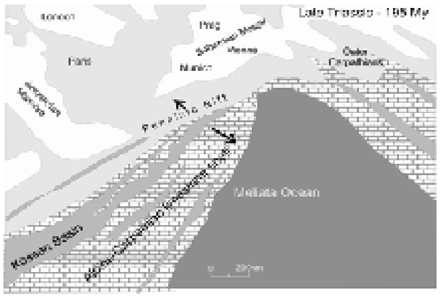
2.Triassic development
Scythian clastics accumulated in a huge deltaic fan system (more than 100 000 km^3). This material was transported by periodical river systems from the area between the Bohemian and the Armorican massifs.

The location of sources of considerable laterally dispersed terrigeneous clastic sediments was assumed in the northern „Vindelician Land“ (Michalík 1992, 1993; Michalík in Feist-Burkhardt et al., 2008; Fig.1). Moreover, the zonality is the same not only in the Eastern Alps, Outer and Central Western Carpathians, but also in the Eastern Carpathians and in subsurface Pannonian units, indicating location of proximal zones with more terrigeneous sediments on the north, and more distal marine facies on the southern margin (Csontos and Vörös, 2007). Quartz sandstones, lithic sandstones, and greywackes with conglomeratic layers fining in a southward direction accumulated in a complex delta system (the Lúžna Formation, Mišík and Jablonský 2000). There, in the more distal parts of the fan, thicknesses increased up to thousand metres and the material consists of siltstones, clays and argillitic limestones.

Arid character of the Triassic climate caused accumulation of thick carbonate ramp- and platform complexes with only several inserted terrigeneous clastic formations, indicating more humid intervals (Scythian, Early Carnian, Rhaetian). An Anisian carbonate ramp developed in arid climate on a wide submerged alluvial plain. It formed a large (300 x 1000 km) shallow carbonate ramp of Gutenstein limestone and dolomite facies with subsidence controlled by gradual sea level rise (20-30 mm/ka) and by compaction of underlying pelitic complexes (another 60-70 mm/ka). Beginning tectonic activity during the late Anisian is documented by tsunamite layers and slump breccias (Michalík et al. 1992). Carbonate platforms, which evolved during the Ladinian, were affected by tensional stress (Michalík 1993, 1994). Sedimentation in intrashelf pull-apart basins was rather slow (Reifling Limestone, Partnach Beds, 4-15 mm/ka) as compared with the rapidly growing reefal margins that were keeping up with the subsidence rate (up to 400 mm/ka). Differential sedimentation rates accentuated the basinal morphology: the basins attained depths of 1200-1500 m at end of the Ladinian, when sea level began to fall (Masaryk et al. 1993). The Julian humid event (possibly caused by an extraterrestrial bolide impact) was a time of mass transport of clastics (about 10 000 km^3) that completely filled the former tensional basins in the Slovako-Carpathian – Austro-Alpine shelf. This rapidly accommodated (500 – 700 mm/ka) material has been carried under occasional monsoonal climate from the adjacent Palaeoeuropean continent.

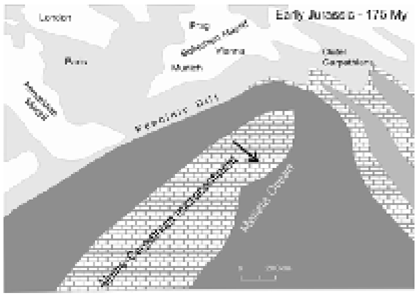
The arid climate, continuing regression and tectonic rise of the Alpine – Carpathian shelf during the late Triassic led to the re-establishment of a carbonate platform system with a continuous reef margin. Extensive back-reef flats (of the Dachstein Limestone and Hauptdolomit formations) separated the sea from Dead Sea-type dry basins with Carpathian Keuper sedimentation. Sedimentation rate of the Carpathian Keuper was seven times slower than the sedimentation rate of the German Keuper, as the clastic supply had to cross the rising Penninic rift valley (Fig.2).



At the end of the Triassic, the Penninic rift rose and formed a continuation of the Middle Atlantic Oceanic rift. Spreading of the Penninic detached the Mediterranean microcontinents from its Palaeoeuropean foreland. The breakage of the Tethyan shelves resulted in the „mega-shear“ model of numerous megablocks separated by strike-slip faults (Michalík 1993, 1994). Lakes and swamps with rich flora and occasional dinosaur fauna (Michalík *et al.* 1976) were created in more distal depressions. Another depression, the Koessen basinal system, was flooded by sea transgression. These semi-isolated sea basins opening in the former shelf gave rise to typical shallow marginal marine sediments with abundant neritic fauna (Michalík 1980). The Triassic – Jurassic boundary beds are marked by several major events: by the termination of carbonate sedimentation, by the occurrence of spherulite containing beds, by C and O isotope excursions, and by the onset of clastic input due to changing climate at the beginning of the Hettangian transgression (Michalík et al., 2009). On the other hand, subduction of the Meliata Ocean during Cimmerian movements led to convergence of both the Alpine-Carpathian and the Adriatic microcontinents.

1. **Jurassic evolution**

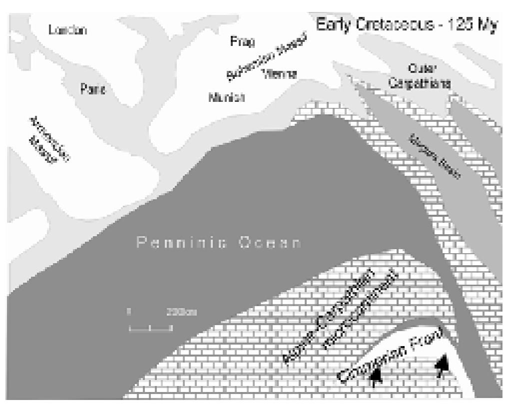
The onset of Jurassic sedimentation was affected by emersion and non-sedimentation in the majority of paleogeographical zones (Michalík in Pieńkowski et al., 2008). During the Meliata Oceanic crust subduction, the southern margin of the Austroalpine - Centrocarpathian microcontinent collided with small blocks in its foreland (Fig.3). Carbonate platforms on it have been emerged and karstified. Also Tatric and Veporic domains much more distant of it have been uplifted. On the other hand, the subsidence continued in the Fatric Domain lying between them. At beginning of the Jurassic, marine claystones with occasional sandstone and sandy organodetrital limestones (the Kopieniec Formation) has been deposited in this basin. During Sinemurian and Lotharingian, quartzose sandstone (the Baboš Quartzite) passing distally into sandy limestones (the Trlenská Formation) indicates the last riverine influx. Crinoidal limestones (the Vývrat Fm) have been deposited on the slope, while deeper hemipelagic setting was characterized by bioturbated marlstones (the Janovky Fm). Red nodular limestones and marls of the Adnet Fm indicated slowered sedimentary rate at the end of Early Jurassic. Also in the Hronic Basin the Lower Jurassic sedimentary cycle started by crinoidal limestones (the Mietusia Fm), and terminated by red nodular limestone.
New middle Jurassic sedimentary cycle started by organodetrital and crinoidal limestone with lateral slope calciturbidite facies passing basinward into siliceous limestones, radiolarites and dark marls (the Ždiar Fm). During Oxfordian, the bottom of the Fatric Zliechov Basin was covered by dark marlstones (the Jasenina Fm), but the adjacent elevated bottom was the place of the Ammonitico Rosso limestone sedimentation. Mid Jurassic sedimentary cycle of the Hronic Unit consists of crinoidal limestones (Vils Formation).



During Late Jurassic, the Ammonitico Rosso facies dominated on the shallows. The southermost part of the West Carpathian inner block is typical with Jurassic pelagic facies. On the other hand, several elevations with neritic limestone sedimentation have been recorded. Sedimentary record here was terminated by Late Cimmerian deformation of the area.

2. Lower Cretaceous evolution

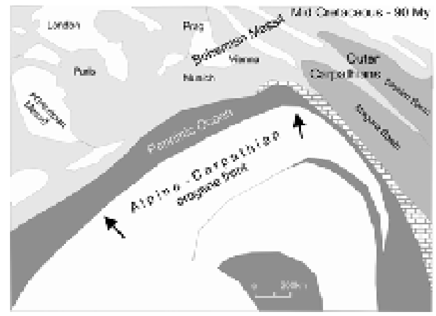
Scarcely preserved source platform limestone complex (the Raptawicka Turnia Fm) consists of microsparitic peletal wackestones with rare oncolites (Staré Hlavy Fm; Michalík et al., 1993) and bioclasts. Shallow marine limestone sequence on more distal elevated blocks starts with Kimmeridgian and Tithonian condensed "Ammonitico Rosso" complex of reddish nodular limestone. On the other hand, the majority of Lower Cretaceous sequences in the Western Carpathians represents mostly products of hemipelagic basinal ("Neocomian") environments. Basinal limestones like the Alpine Oberalm Formation contain calciturbidite debris (the Barmstein Limestone) and are followed by schistose marly or cherty limestones (the Schrambach-, Lučivná formations). Pull-apart Fatric Basin was filled by Upper Jurassic dysoxic marls (the Jasenina Fm), covered by pelagic Berriasian "biancone" limestones (the Osnica-, Padlá Voda formations). The time span of hemipelagic limestones (the Mráznica-, Hlboč- and Kościeliska formations) is Late Valanginian in the Manín Unit, but Valanginian to Aptian in more distal basinal infillig of the Zliechov Basin. Important Late Cimmerian tectonic event (the Oravice Event, Michalík et al., 1996), was accompanied by a compression in southernmore units and by input of quartz debris with abundant chromium spinel grains into the basin (Michalík in Voigt et al., 2008; Fig.4.).



The "Urgonian" (Upper Hauterivian-Lower Albian) sequence starts with deposition of slope- and submarine delta fans derived from carbonate platforms prograding basinwards (Muráň Fm, Michalík and Soták 1990, Bohatá Fm, Podhorie Fm, etc.). The carbonate platform cores were mostly destroyed by erosion (Wysoka Turnia-, Manín formations). Warming during Aptian caused decreasing oxygenation and increasing of carbon content in the basinal sediments (the Párnica-, Muránska Lúka-, Osobitá formations).

3. Mid-Cretaceous synorogenic formations

During Middle Albian, carbonate platforms were submerged and covered by dark marls (Zabijak- and Butkov formations). The basins in central Carpathians were mostly filled by thick (300-600 m) brownish, often bioturbated gray marls with siltstone intercalations, or even olistoliths (the Poruba Fm), passing into Cenomanian rhytmic sandstone-claystone sequence (Belušské Slatiny Fm). At this time, convergence between Gonwana- and Laurasian margins started, resulting in subduction of the Penninic oceanic bottom, in destruction of former basinal systems and folding. A complex stacked pile of superposed units comprising the pre-Alpine basement, its Mesozoic cover, and superficial nappes originated during Turonian in Central Carpathians (fig.5.).



The Upper Cretaceous "Gosau" developments

After the major compression finished, folded structures collapsed. New tensional basins evolved in the middle of orogenic system (Plašienka et al., 1997). Variegated breccias of local material, cemented by yellowish and red argillaceous matrix filled cavities, fissures and depressions on the surface of carbonate complexes (Michalík 1984, 2000).

On the other hand, basinal sequence starts with fresh-water Turonian / Lower Coniacian limestones with fresh-water algae (Pustá Ves Fm). Braided river- and subaerial delta clastics (Ostriež Fm) start Senonian marine sequence composed of thick flysch of alternating graded calcareous sandstones, variegated (mostly red) marls, sandy marls and sandy limestones. On the other hand, tension and opening of the flysch basins continued in Outerr Carpathians until Oligocene when Alpine and Carpathian orogenetic arcs formed (Fig. 6.).

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