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Mid-Cretaceous (120-80 Ma) orogenic processes in the Central Western Carpathians: brief review and interpretation of data

DUŠAN PLAŠIENKA

Geological Institute of the Slovak Academy of Sciences, Dúbravská cesta 9, 842 26 Bratislava, Slovakia

Abstract. The scenario of the mid-Cretaceous (120-80 Ma, i.e. Aptian to Campanian) tectonic processes in the Central West Carpathian area includes collapse of the thermally softened supra-Veporic thrust stack and exhumation of the Veporic metamorphic core complex by orogen-parallel extensional unroofing, triggered by underthrusting of the Fatric (Krížna) crust accompanied by detachment of the sedimentary filling of the Fatric basinal area to form the Krížna cover nappe. This was later gravitationally emplaced northward above the Tatric cover and followed by gliding of Hronic (Choč) and Silicic cover nappes. In the early Late Cretaceous, contraction affected the outer, northern Tatric margin of the CWC facing the Penninic-Vahic oceanic realm. All these processes exhibit an outward (generally northward) polarity.

Key words: Central Western Carpathians, paleo-Alpine orogenesis, crustal stacking, nappe emplacement

Introduction

The Cretaceous stage, mid-Cretaceous times in particular, was the main period of tectogenesis of units in the Central Western Carpathians (CWC). The CWC are defined here as an early Alpidic orogenic belt located between two principal, more or less latitudinally trending oceanic sutures: the Penninic-Vahic (opened in the Middle Jurassic, closed in the latest Cretaceous to Early Tertiary) in the north and the Meliata-Hallstatt (opened in the Middle Triassic or earlier, closed in the Late Jurassic) in the south. However, the exact position of especially the latter suture is a matter of controversy and several branches of both oceanic domains may be present in the Carpathian edifice (e.g. KOZUR & MOCK, 1995). The CWC, as a lateral analogue of the Austroalpine system, are composed of Tatric, Veporic and Gemeric thick-skinned basement sheets, and Fatric, Hronic and Silicic cover nappe groups. Paleogeographically only the Fatric (Križna) nappes were clearly positioned within the CWC basement area – between the Tatric and Veporic domains. The homeland of the Hronic (Choč) nappes remains disputable, though most probably located still northwards of the Meliata-Hallstatt oceanic channel. The Silicic units with obvious "southern" affinities, which are often underlain by Meliatic slices, might be derived from the southern margin of this ocean (HÓK et al., 1995). Nevertheless, after being emplaced during the Late Cretaceous, the Silicic nappes became integral constituents of the CWC.

The aim of this paper is to register the most important, sufficiently precisely (directly or undirectly) age-constrained paleotectonic data and to interpret them tentatively in order to reconstruct the temporal and spatial interplay among different tectonic processes operative during the main phase of nappe thrusting in the CWC.

Mid-Cretaceous events

In the following paragraphs, the principal data coming from the stratigraphic, sedimentologic, magmatic, metamorphic, geochronologic and structural rock record are listed and their tentative interpretations are presented. Due to the limited extent of the present paper, only the most important general articles and some newest results are quoted. Processes, which probably have left the records discussed, are synoptically depicted in Fig. 1. The timescale by GRADSTEIN et al. (1994) is adopted.

Period 120-110 Ma (Aptian to early Albian). Almost no direct data exist from the Meliatic, Silicic, Hronic, Gemeric and south Veporic units, except some radiometric datings: one solitary formation plateau age of amphibole from the Veporic basement (115 Ma, KOVÁČIK and MALUSKI, 1994) and the age of Alpidic remobilization of U, Mo and Cu vein mineralization in the northern Gemeric domain (130±20 Ma, U-Pb isotopic dating of higher-grade veins and 115±10 Ma, Pb model age of low-grade veins - ROJKOVIČ et al., 1993). At the north Veporic – south Fatric interface (Veľký Bok unit), pelagic sedimentation terminated and no younger rocks are known. Huge olistostromatic bodies derived from the south were formed in the Fatric Zliechov basin (JABLONSKÝ & MARSCHALKO, 1992). Ephemeral "Urgonian" carbonate platforms gradually ceased in the north Fatric - south Tatric domains, rimmed by allodapic clastic fans (MIŠÍK, 1990; MICHALÍK & SOTÁK, 1990; MICHALÍK, 1994), and generally pelagic deposition continued in the Fatric-Tatric-Vahic area. Some siliciclastic turbidites of local sources were deposited in the northern Tatricum (Solírov fm., JABLONSKÝ et al., 1993). Areally extensive, though volumetrically negligible submarine hyalobasanitic volcanism in the Fatric and Tatric region (HOVORKA and SPIŠIAK, 1993) is a very important paleotectonic signature.

The above facts may be interpreted as records of a gradual thermal equilibration and slow uplift of the southern "supra-Veporic" collisional zones ("Andrusov mountain range" in Fig. 1) and a northward progradation of contraction to the Veporic-Fatric margin (Veľký Bok domain). Its imbrication produced the topographic gradient controlling the mass slope resedimentation in the Fatric Zliechov basin. Contemporaneously, an extensional impulse occured in the Fatric-Tatric foreland which caused rejuvenization of normal faulting and block tilting accompanied by small portions of mantle-derived lavas piercing the strongly thinned crust. The carbonate buildups grew on elevated edges of tilted blocks, probably assisted by foreland bulge upbending and the sea-level drop.

Period 110-90 Ma (middle Albian to late Turonian). Only scarce, sufficiently age-constrained data are available in the Meliatic-Gemeric-Veporic-Silicic-Hronic areas (except some thermochronological in the Veporic basement, summarized by KOVÁČ et al., 1994). The Alpidic metamorphic peak in the Veporicum has been recently estimated to maximum 550-600 °C and 8-10 kbar in the deepest basement unit (Janák, unpublished) and to at least 400 °C and 6-8 kbar in the Permian cover (JANÁK & PUTIŠ, unpublished data), the low-grade metamorphic imprint in the overlying Gemericum is documented by the 105 Ma plateau age from the Permian sediments (DALLMEYER et al., 1994). The thrusting-related structural record in the rear parts of the Fatric Krížna cover nappe and in the Veľký Bok units (their décollement and stacking) is generally well known (PLAŠIENKA 1983, 1995a and references therein) and partly dated (101 Ma, K-Ar on white micas - NEMČOK & KANTOR, 1989). After the rapid submersion of Urgonian carbonate platforms, only pelagic and synorogenic coarsening-upward flysch sedimentation (Poruba fm.) is present in the Fatric (up to the early Cenomanian) and Tatric (up to the early Turonian) zones. The flysch conglomerates contain, except common CWC lithofacies, also a lot of "exotic" pebbles of disputable provenance (see reviews by MIŠÍK et al., 1981; MIŠÍK & MARSCHALKO, 1988). However, only pelagites are present in the Vahic Belice unit (PLAŠIENKA et al.,1994). Shortening within the Tatric basement began already to the end of this stage, as some contractional structures at the South Tatric ridge - Šiprúň basin interface (Nízke and Vysoké Tatry Mts.) are partly saled by the superimposed Krížna nappe (Fig. 1).

Interpretation: the thermal equilibration and peak of Barrowian metamorphism was probably reached in the deeply buried (more than 20 km!) Veporicum some 110-100 Ma b.p., thermal softening enabled its later unroofing. However, during the mid-Cretaceous stage, a rapid underplating of the Fatric basement below the Veporic one forced compressional upheaval of the Veporic-Gemeric-Meliatic ("exotic") pile, the top of which became exposed to intense erosion and fed the neighbouring Klape-Poruba flysch basin by coarse, mostly "exotic" clastics (the Klape unit is considered here as a Fatric element, adopting the view of PLAŠIENKA, 1995b). This acceleratively developing situation is schematically outlined in Fig. 1. Tatric Urgonian platforms were submerged due to flexural downbending of the lower orogenic plate, which contributed also to the development of fore-arc or trench-type flysch basins. Contemporaneously, the sedimentary succession of the Fatric basin was detached from its underthrust substratum along the horizon of Upper Scythian shales and evaporites and formed up an imbricated fold-and-thrust wedge accreted to the upper Veporic plate (cf. PLAŠIENKA & PROKEŠOVÁ, 1996). Inversion started in the inner Tatric zones.

Period around 90 Ma (late Turonian). Extensive surface overthrusting event in the CWC: emplacement of the Fatric (Krížna) and Hronic (Choč) décollement cover nappe systems, narrowly constrained by the youngest Tatric cover sediments below the Krížna overthrust plane (lower Turonian) and the oldest basinal post-nappe Gosau deposits atop the Hronic nappes (upper Coniacian in the western part of the CWC). Structural features at soles of superficial nappes include overpressured carbonate tectonic breccias, sometimes entirely dissolved ("macrostylolite" of JAROSZEWSKI, 1982), without a considerable deformation effect on the footwall rocks (PLAŠIENKA & SOTÁK, 1996). The emplacement of the Krížna nappe is recorded by extensional structures superimposed on older contractional ones in its rear and dorsal parts (PROKEŠOVÁ, 1994).

Interpretation: structural associations and relationships in the cover nappes point to the final gravity gliding emplacement mechanism, though push from the rear and gravity spreading might contributed as well, especially in the first phases of thrusting. The necessary topographic gradient was produced by overstepping the frontal Tatric ramp in the case of the Krížna nappe (cf. PLAŠIENKA and PROKEŠOVÁ, 1996). The detachment and driving mechanisms of Hronic nappes, especially of those floored by thick Upper Paleozoic sedimentary and volcanic sole (Ipoltica group), is more difficult to interpret. Probably Hronic nappes were derived from southern, rapidly uplifting zones juxtaposed to the "Andrusov Mountain Range" in the SW (?) which escaped considerable Early Cretaceous stacking. The

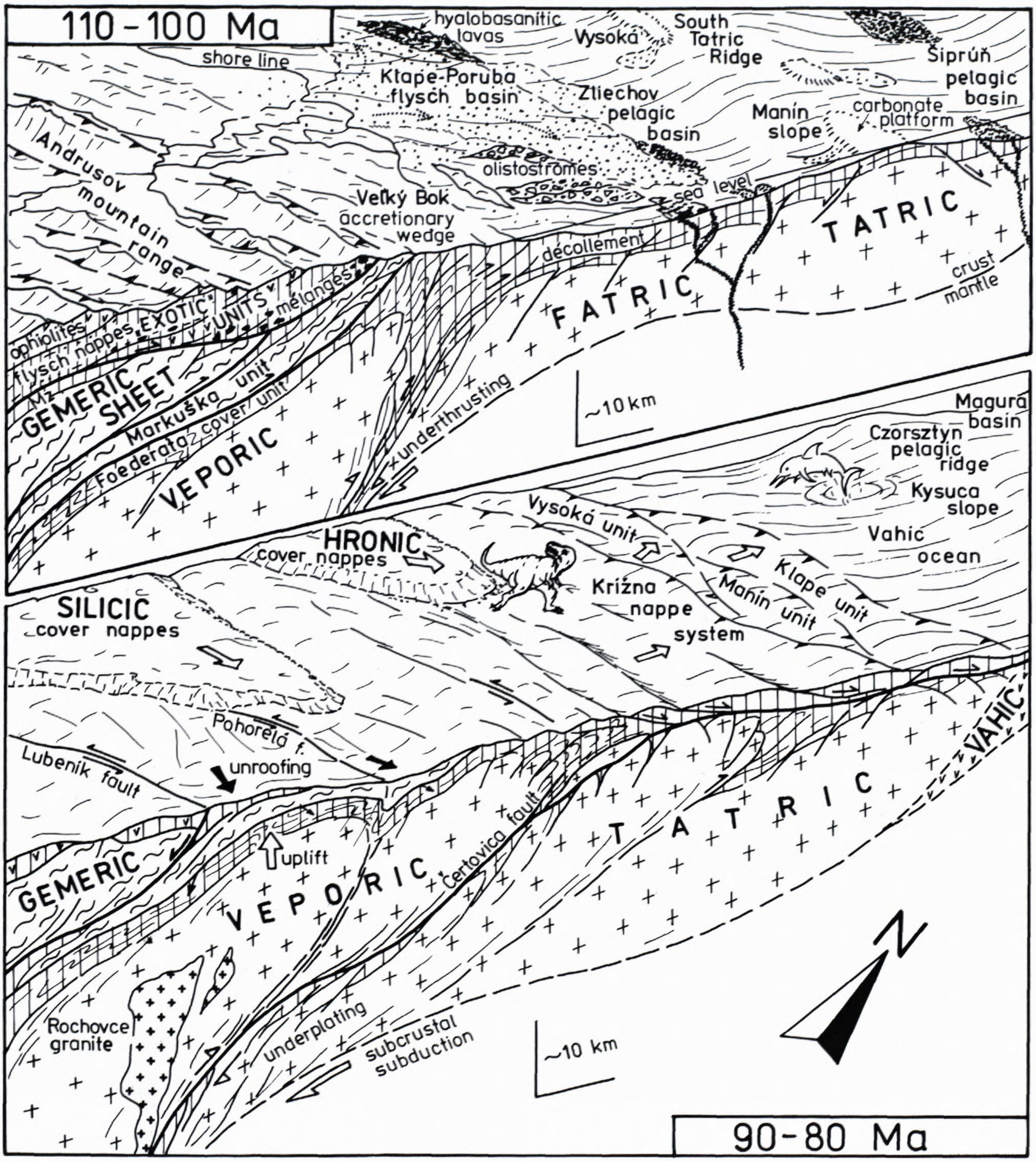

Fig. 1. Schematic cartoon synoptically depicting the major mid-Cretaceous tectonic events in the Central West Carpathian area.

Silicic units might be originally related to the Hronic ones, their final emplacement event seems to be younger, however.

Period 90-80 Ma (latest Turonian to early Campanian). Most of the cooling isotopic ages from the Veporic metamorphic core complex fall within this time interval (see review by KOVÁČ et al., 1994, and references therein). Cooling accompanied ductile extensional unroofing of the Veporic core with top-to-the east kinematics in its eastern part (HÓK et al., 1993; PLAŠIENKA, 1993). Orogen-parallel extension occured under a general N-S contractional regime with sinistral transpression along SW-NE trending wrench zones (e.g. the Pohorelá fault zone - HÓK & HRAŠKO, 1990; PUTIŠ, 1991; MADARÁS et al., 1994). Extension culminated by intrusion of the Rochovce granite in the southern Veporicum (81 Ma zircon age - HRAŠKO et al., 1995). The Rochovce granitic body is an alkaline intrusion generated by anatexis of crustal rocks and emplaced in an extensional regime in higher crustal levels (RADVANEC, 1995) with a contact aureole superimposed on regional mineral assemblages. Unmetamorphic Silicic nappes in the Veporic and Gemeric area overrode a deeply denuded substratum, therefore a pronounced metamorphic and structural gap exists at their bases, representing some 15-20 km of missing rock column in-between. Sporadically preserved Lower Senonian sediments in the CWC (except their northern rim) consist of probably Santonian continental conglomerates and fresh-water limestones and lower Campanian open-marine variegated marls. The Vahic Belice succession exhibits the change from eupelagic to coarsening-upward flysch sedimentation at the Turonian/ Coniacian boundary (PLAŠIENKA et al., 1994). Lower Senonian sediments along the outer Tatric edge in the Periklippen zone show variable compositions and sedimentary enviroments, from transgressive and then deepening succession of the Gosau group up to continuos (?) mid- to Upper Cretaceous pelagic and flysch sequences (e.g. SALAJ, 1994a, b, 1995).

Interpretation of these data considers extensive gravitational collapse of the southern CWC zones triggered by contractional uplift of the Veporic core, probably due to underplating of a buoyant Fatric crust and enhaced by strain softening after thermal relaxation of the Lower Cretaceous thrust stack. The rapidly exhumed Veporic cover and basement units were in turn immediately overthrust by unmetamorphic cover nappes of the Silicic system. The Veporic cover and upper parts of the basement were highly mobile during low-angle extension which superposed sheet-like units with discontinuously decreasing metamorphic overprint and "condensed" isograds. The area was sinking at least until the middle Campanian, when it was covered by an epicontinental sea (partly also as a consequence of the sea level rise). No record of this stage has been ascertained in the northern (Tatric) area of the CWC, which was most probably a dry land exposed to karstification of especially the Triassic carbonate complexes of the highermost Hronic nappes (MICHALÍK and ČINČURA, 1992; ČINČURA & KÖHLER, 1995), but zones along the northern CWC margin underwent the main compressional phase after the conversion of the Tatric/Vahic passive margin into the active one (PLAŠIENKA, 1995b, c). The frontal Fatric-Hronic nappe elements partly glided into a position above the Vahic in front of the Tatric edge, where they became incorporated into fold-and-thrust complexes accreted to the toe of the upper (Tatric) plate. Sedimentary cover of the oceanic Vahic basement was partly detached to form a subcretionary complex underneath the Tatric toe (PLAŠIENKA, 1995d). It follows that the converging zone was composed of sectors where the Tatric/Vahic contact was buried below the Central Carpathian nappe units topped by compressional piggyback forearc-type basins and sectors where this contact was exposed at the surface and trench-type wildflysch sedimentation occured atop the lower Vahic plate (Belice unit, PLAŠIENKA, 1995d, Fig. 8).

Conclusion

The above scenario clearly illustrates the northward propagation of mid-Cretaceous orogenic processes in the CWC area. In the time interval considered (120-80 Ma), the southern Veporic, Gemeric and Inner Western Carpathian zones were the site of post-collisional (after suturing of the Meliata-Hallstatt ocean) thermal relaxation and gradually accelerating uplift triggering the extensional collapse of the Veporic metamorphic core complex. Simultaneously, the shortening axis migrated northwards to attack the north Veporic - south Fatric and later the Tatric zones. The emplacement of Fatric and Hronic nappe systems appears to be a very time-limited surface event, being driven by gravitational spreading and gliding towards the foreland, generally not related to the main compressive phases in the respective paleogeographic domains. The passive to active margin inversion of the Tatric/Vahic interface during the early Senonian fits well the overall shortening polarity within the CWC. Consequently, the mid-Cretaceous contraction in the CWC realm had to be driven by geodynamic processes other than subduction of the Penninic-Vahic slab along their outer edge.

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