Evolution of the Outer Carpathian Accretionary Wedge

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The Western Carpathians are part of a great arc of mountains. They are subdivided into the Inner and Outer Carpathians and separated by the Pieniny Klippen Belt suture zone. The Outer Carpathians are composed of Late Jurassic-to-Early Miocene flysch deposits and are completely uprooted from their basement. The outer part ranges form the Late Oligocene/Middle Miocene accretionary wedge composed of several nappes, which are sub-horizontally overthrust onto the Miocene deposits of the Carpathian Foredeep.

The Middle Jurassic Outer Carpathian remnant oceanic basin developed between the colliding European continent and the intra-oceanic arcs. During the Early Cretaceous the rifted European margin was incorporated into the Outer Carpathian basin. The continued development of the basin was controlled by normal fault and post-rift thermal subsidence. Like the other orogenic belts, the Outer Carpathians were progressively folded towards the continental margin. This process was probably initiated in the Silesian basin by a post Cenomanian southward subduction, which caused the uplift of the Silesian ridge. The Paleocene accretion of the Pieniny Klippen Belt initiated the growth of the Magura accretionary wedge as well as intensive subsidence and deposition in the southern part of the Magura Basin. During the Priabonian the Outer Carpathian basin was transformed into a collision-related foreland basin. This stage was caused by a southerly subduction of the Magura Basin beneath the PKB. During the Early Burdigalian rise of sea level the restored width of the residual flysch basin probably reached at least 150 km.

This was followed by the Intra-Burdigalian folding uplift and overthrust of the Outer Carpathians on the foreland platform. During these movements the front of the orogene reached a position located about 50 km south from the present-day position of the Carpathians. The load of the Carpathian accretionary wedge caused bending of the platform basement and the development of the moat- like flexural depression (inner foredeep), which was filled by coarse clastic deposits. This was accompanied by the development of large – scale slides along the frontal part of the Sub-Silesian Nappe. These slides form olistoplaques and gravitational nappes known as the "Old Styrian nappes" or as the Sucha and Zamarski formations (flysch olistoplaque). In the Cieszyn area this overthrust reached the more or less present-day position of the Carpathians. The olistoplaque formation was postdated by the Karpatian period of intensive subsidence and deposition in the inner foredeep, which was filled with coarse clastic sediments of the Stryszawa Fm. The deposition of the Stryszawa Fm. was followed by Late Karpatian erosion, which was caused by an uplift of the peripheral bulge (Cieszyn- Slavkov Paleo-Ridge). The erosion on the northern flank of the CSPR began to develop simultaneously with the W-E and NW-SE trending graben, bounded by normal faults. During the Late Karpatian-Early Badenian time the subsiding grabens were successively filled with slope deposits nearshore Dębowiec Conglomerates, and were eventually flooded by relatively deep-sea water (marly mudstones of the Skawina Fm.) During the Badenian the axes of the extensional grabens migrated NE (Zawada and Krzeszowice grabens). The Late Badenian drop of sea level and climatic cooling initiated a salinity crisis in the Carpathian foreland basin. Following evaporite deposition the basement of the outer foredeep was uplifted and a part of the foredeep was affected by erosion (e.g. Rzeszów Paleo-Ridge). This event was followed by a telescopic shortening of the Carpathian nappes (Intra Badenian compressive event). This is documented by a movement of at least 12 km of the Magura and Fore-Magura units against the Silesian unit, as well as the Silesian unit against the Sub-Silesian unit and finally the tectonic reduplication of the Sub-Silesian unit. The present-day position of the Carpathian nappes reached the post-Sarmatian time.

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Migmatites and Leucogranites Produced by Muscovite Dehydration Melting on the Example of the Strážovské Vrchy Mts. (Suchý Core), Western Carpathians

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The Variscan basement outcropping in the Suchý core is built by high-grade metamorphic rocks and granitoids. The western slopes are formed by migmatites, gneisses, amphibolites and leucogranites. Going inward the core the migmatites change from metatexites to diatexites, which in turn are intruded by leucogranitic pegmatite veins and garnetiferous aplite. While the metatexites have well developed leucosomes and melanosomes, alternating with mesosomes, the diatexites are characterized as inhomogeneous, schlieren granite. Apparently younger fine- to medium-grained tonalites /grandiorites cut the migmatite complex. All these varieties are generally classified as S-type granitoids (Petrík et al., 1994).

Petrography

Migmatites: The metatexites have uniform plagioclase composition An25±3, neosome is split into (1) melanosome dominated by coarse-grained biotite (100Mg/(Mg+Fe) = 48, Ti=0.28/220) ± prismatic sillimanite, muscovite and the increased amount of accessory apatite and monazite, and (2) leucosome composed of plagioclase (An20-25), quartz, small amount of K-feldspar, biotite and sillimanite, rarely accompanied by garnet. Mesosomes are fine-grained, more mafic and more homogeneous, some layers also contain sillimanite. A late muscovite is common in all varieties, typically overgrowing fibrolitic sillimanite. Diatexites are coarse-grained with granitic texture and rich in sillimanite (up to 6 vol.%) and late muscovite. This sillimanite was interpreted as a result of acid leaching by Korikovsky et al. (1987). The mafic schlieren may be several cm thick, they are composed of biotite (70–90 %), quartz, sillimanite, K-feldspar and plagioclase (An30-20). Accessories (apatite, monazite and zircon) are significantly concentrated in biotite. The abundant sillimanite is invariably enclosed by the late muscovite.

Garnet aplites are fine-grained rocks with panallotriomorphic texture, composed of cross-hatched microcline, sodic plagioclase (An10-15) and undulatory quartz. Subhedral to poikilitic garnets are almandine-spessartine in composition (Pyr8--11Alm71-72Sps15-18Grs2) showing no distinct zoning. The late muscovite also encloses fibrolite and forms symplectites with quartz.

P-T conditions and origin of migmatites

Thermobarometric results, obtained by TWEEQU method (Berman, 1991) and the TWQ 2.01 software, yielded the temperatures of about 680 °C and pressures of 500–600 MPa for migmatites, and 630–660 °C and 300–500 MPa for aplites in the central part of the Suchý core. These P-T conditions are close to the dehydration-melting of muscovite and granite solidus. They are interpreted to record not the peak of metamorphism (partial melting) but a retrograde stage upon cooling and melt solidification when crystallization-hydration reactions between crystallizing melt and restite may have occurred.

The leucosomes are interpreted as products of muscovite dehydration melting of muscovite-rich layers in a metapelitic protolith according to reaction Mus + Plg + Qtz = Kfs + Sill + L. The prismatic sillimanite concentrated with biotite into mafic selvedges (melanosome). The muscovite dehydration melting commonly produces only limited amount of melt (e.g., Stevens and Clemens, 1993; Spear et al., 1999) which is characteristic of migmatites. Although, the calculated temperatures derived from the garnet-bearing samples did not exceed 700 °C, it is probable that the peak temperature was actually ca. 50 °C higher, reaching the muscovite dehydration melting curve (e.g., Vielzeuf and Holloway, 1988). Therefore, the late muscovite may represent a retrogressive, rehydration stage, having formed as Mu ± Qtz symplectites by the consumption of sillimanite and K-feldspar.

The diatexite (biotite granodiorite) may represent an advanced stage of muscovite dehydration melting where schlieren (biotite + sillimanite + quartz + accessories) are thought to have a restite origin. The minor garnet supports only incipient biotite dehydration melting in the metatexite/diatexite zone according to reaction Bio + Sill = Gr + Kfs + L (Spear et al., 1999). On the other hand, garnet aplites originated from a two-mica metapelites probably at higher temperatures involving both muscovite and biotite dehydration melting, producing peritectic garnet and K-feldspar (e.g. by the reaction Bio + Sill + Qtz + Ab = Kfs + Gar + L). This process, however, requires higher temperatures (about 800–850 °C) than those recorded by thermobarometry (ca. 630–660 °C). Therefore, the latter temperature refers rather to near-solidus cooling than a peak temperature. While diatexites represent a cooler, less mobile, and restite-rich anatectic melt more or less confined to migmatites, the aplites are viewed as hotter, drier and mobile anatectic melts that penetrated into gneissic mantle.

The muscovitisation has consumed much of K-feldspar and some sillimanite (typically only fine-grained fibrolite remnants are preserved in muscovite). This strong rehydration occurred in all migmatite types and aplites/pegmatoids of the Suchý core except fine-grained, peraluminous biotite tonalites and allanite--bearing tonalites cutting the migmatites. This implies that the water-rich fluid was derived locally, presumably from the crystallizing anatectic melt. In view of such re-hydration reactions, the observed sillimanite/muscovite textural relations do not require the open-system mechanism involving alkali leaching and removal of alkalies as suggested by Korikovski et al. (1987).

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Early Stages of Tectonic Evolution of the Pieniny Klippen Belt

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The Pieniny Klippen Belt (PKB) of the Western Carpathians is often characterized as a tectonic megabreccia, mélange, or even it was speculated to represent a chaotic sedimentary body – olistostrome. However, this peculiar "block-in-matrix" structural appearance of the PKB is mainly result of later stages of the deformation history of the PKB units, governed by along-strike transpressional and transtensional movements (e.g. Kováč and Hók, 1997). On the other hand, little is known about the dynamics of pre-orogenic rifting events and timing, geometry and kinematics of the earliest contractional phases. In this contribution a review of data about the pre-contraction history of the principal PKB units and a tentative geodynamic interpretation of Jurassic-Early Cretaceous rifting processes in the PKB and related areas are presented, as well as a model of the initial compressional stages in the area is outlined.

Based on the analysis and paleotectonic interpretation of the sedimentary rock record, three principal rifting phases are discerned in the PKB and related units: