High-resolution morpho-tectonic profiling across an orogen

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English summary

This research focuses on the morphological evolution and exhumation history of the SE Carpathians. This orogen is the result of plate convergence and continental collision as part of the curved Alpine-Carpathian system and formed in response to the Middle Triassic to Quaternary evolution of several tectonic blocks. The study area can be divided into: internal nappes emplaced during the Middle Cretaceous (Aptian-Albian) shortening, external nappes emplaced during the Miocene thrusting over the European passive continental margin and resulting in the Late Miocene docking of the orogenic system against the European and Moesian platforms; and lastly, the foreland basin (i.e. Focşani basin) developed in front of the nappe thrusts since the Late Miocene and the intramontane basin (i.e. Braşov basin) formed since the Pliocene on top of the internal nappes.

Although the SE Carpathians have been widely studied over the last decades, there are still unsolved issues, some of which are being addressed by this research. Did the SE Carpathians remain quiet during the Paleogene time, when adjacent regions were subject to deformation, shortening and exhumation? For instance, Late Oligocene-Early Miocene exhumation occurred in the South Carpathians and Late Oligocene shortening was recorded in the western part of the Transylvanian basin, while Paleogene sinistral transpression affected the Eastern Balkans and their continuation into the Black Sea basin etc. This study focuses on determining if similar deformations took place in the SE Carpathians.

Another question that plays is it can be explained that the Cretaceous rocks of one of the external nappes (i.e. Marginal Folds) are presently placed at elevations of ~1500 m in the study area, while north and south of it, these deposits are found at a few kilometres depth? When did the strong tilting (vertical at contact with nappe thrust) occur, of the Uppermost Miocene-Quaternary strata on the western flank of the foreland basin (i.e. Focşani basin), in the aftermath of the Late Miocene continental collision? How can be explained the vertical motions experienced by the Lowermost Pleistocene conglomerates of the foreland basin, which are presently placed at elevation of 1000 m on the basin flank in the west and are found at depth of 1000 m, 10-15 km eastward in the basin centre?

To deal with these issues, a multi disciplinary approach has been conducted during this PhD research. The overall morpho-tectonic evolution of the SE Carpathian orogen from Cretaceous to Holocene was constrained by quantifying the amplitude, timing and rate of vertical motions. These constraints are evaluated against a W-E-orientated geological cross-section of 175 km across both the orogen and the adjacent basins. The cross-section starts in the Transylvanian basin, passes through the internal and external orogenic nappes and ends on the western tilted flank of the Focşani basin. Various dating methods are applied to study the exhumation history (low-temperature thermochronology) and geomorphological evolution (dating of erosional surfaces/river terraces), while also some underlying mechanisms in account of the shortening and uplift are addressed.

The methodology used during this study consists of: (1) mapping of geomorphological features (i.e. monocline structure, river terraces and river channel morphology) based on field observations and DEM analyses to derive the amplitude of vertical motions during the Quaternary; (2) Infrared stimulated luminescence (IRSL) dating was applied to loess sequences that cover erosional surfaces (i.e. monocline structure and river terraces) in order to derive loess accumulation rates and indirectly terrace formation ages and river incision rates; and (3) AFT and (U-Th)/He methods constrained the timing and amplitude of vertical motions during the entire (Cretaceous to Quaternary) contractional history of the SE Carpathians.

Geomorphological results are described in chapter 2 and show how two periods of uplift affected the external Carpathian nappes and the Focşani foreland basin during the late Early Pleistocene and the late Middle Pleistocene-Holocene, respectively. The former accounts for 750 m of uplift and 9°ENE monocline tilting of the Lowermost Pleistocene conglomerates on the western flank of the Focşani basin, while the latter documents ~250 m uplift of the Middle Pleistocene-Holocene river terraces in the most external nappe.

New IRSL ages are acquired for loess deposits in chapter 4 and further inferences on terrace formation and river incision indicate that the highest rates of river incision and associated uplift during the late Middle Pleistocene-Holocene period have been recorded in the external nappes. Here, these movements have been correlated with local tectonic events due to high-angle reverse faults that affected the basement underlying the Carpathian nappes. The amplitude of river incision/uplift decreased laterally towards the foreland and hinterland basins, where climatic changes might have been a significant controlling factor in terrace formation.

The findings from the AFT and (U-Th)/He methods are discussed in chapter 5 and point to two shortening phases. The first kinematic phase, considered in this study, is the late Early Cretaceous to Late Miocene progressive evolution of an accretionary wedge. New finding in this research is that the SE Carpathians experienced exhumation during the Eocene-Oligocene, which suggests that contraction continued during the Paleogene, which is different from the quiescence previously thought for this period. The second phase is characterized by the Latest Miocene to Present post-collisional high-angle reverse faulting. Significant for this period is the fast exhumation of the central external nappe (i.e. Marginal Folds) during the late Early Pleistocene, which induced the tilting of the Lowermost Pleistocene strata from the foreland basin. The two shortening phases resulted from the eastward-foreland-vergent thrusting from Early Cretaceous to present-day, subsequent to the Late Jurassic-Earliest Cretaceous oceanic spreading in the Transylvanides and the Ceahlău-Severin domains.

The overall morpho-tectonic evolution of the SE Carpathian orogen from Cretaceous to Holocene has been summarized in chapter 6 and encompass three stages: (1) the late Early Cretaceous to Earliest Oligocene subduction stage is related to the progressive growth of an accretionary wedge, partly below sea-level, resulting in emplacement of the internal nappes; (2) the Oligocene to Late Miocene subduction to collision stage is related to the continuous growth of the accretionary wedge with emplacement of the external nappes and continental collision during the Late Miocene; and (3) the Latest Miocene to Present post-collision stage is characterized by high-angle reverse faulting that affected the basement underlying the orogenic nappes, resulting in uplift and tilting of the Up-

permost Miocene-Holocene strata of the foreland basin. Chapter 6 also points out that glaciation might have had a greater influence on river incision and terrace formation in the internal orogenic nappes, while in the external nappes and the foreland basin, the river terraces were controlled by the above mentioned high-angle reverse faults.