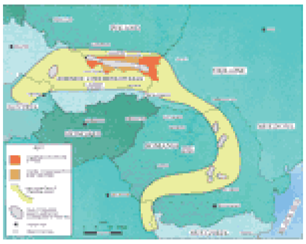
to Generate Late-Collision, Calc-Alkaline and Alkaline, Mafic Volcanism



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Partial delamination of continental mantle lithosphere, uplift-related crust-mantle decoupling, volcanism and basin formation: a new model for the Pliocene-Quaternary evolution of the southern East-Carpathians, Romania

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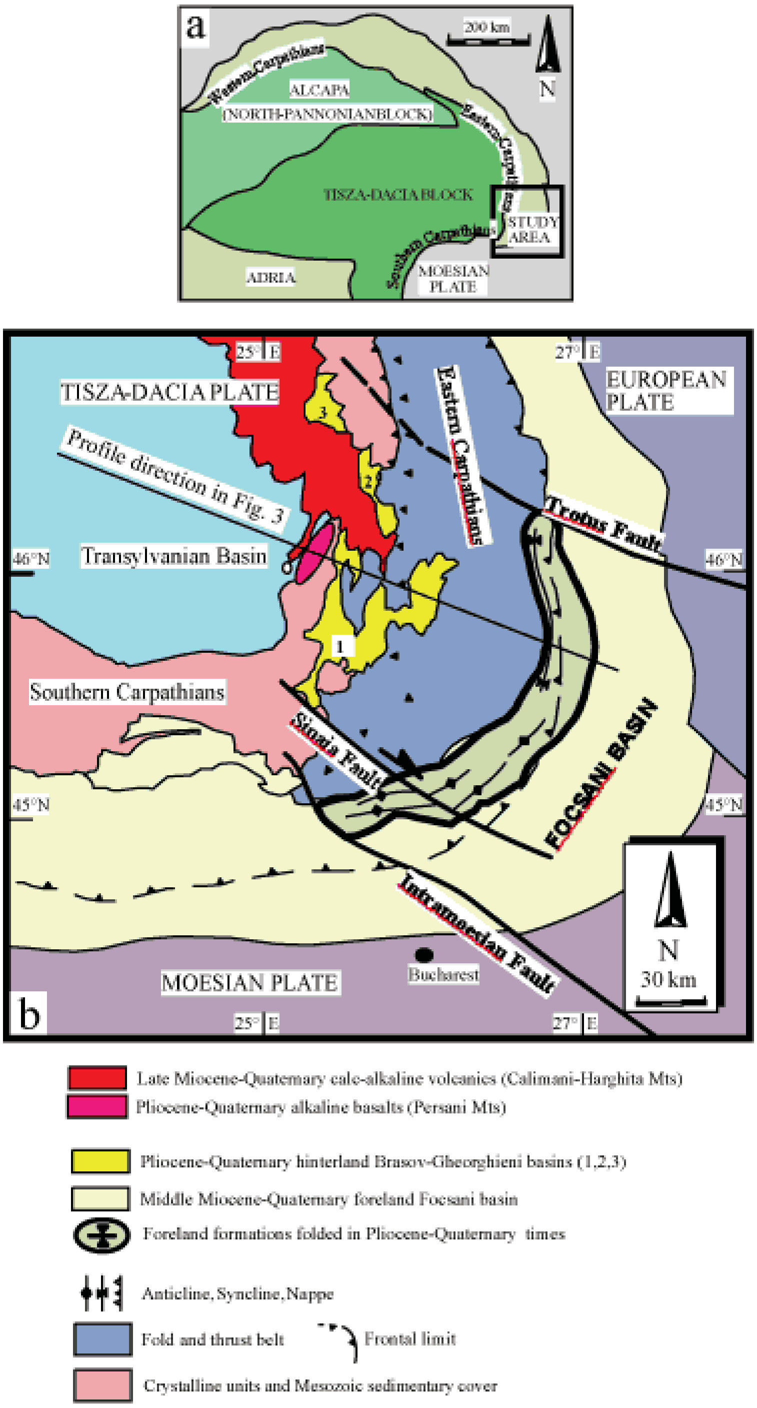
We propose a geodynamic model for the Mid-Miocene to Quaternary evolution of the southern East-Carpathians (Figure 1) in order to explain the relationships between shallow and deep geological phenomena that occurred synchronously during late-collision tectonics (*Chalot-Prat & Girbacea*, 2000).

Figure 1 (Overleaf): a. Tectonic blocks (ALCAPA and Tisza-Dacia) whose convergence and continental collision with the European Plate resulted in the formation of the Carpathian arc during Tertiary times (after Csontos, 1995); b. Location of the study area in the southern Eastern Carpathians (simplified after Girbacea & Frisch, 1998). Click to enlarge.



In this area, an active volcanic zone has cross-cut, for the last 2 My, the suture between the overriding Tisza-Dacia and subducting European continental plates. Mafic calc-alkaline and alkaline magmas (the south Harghita and Persani volcanoes) erupted contemporaneously.

These magmas were supplied by partial melting of the subcrustal heterogeneous mantle lithosphere of the subducting, and not the overriding, plate (*Chalot-Prat & Boullier*, 1997). This shallow mantle lithosphere corresponds to a residual mantle which recorded at least two distinct events of metasomatism well before the eruptions.

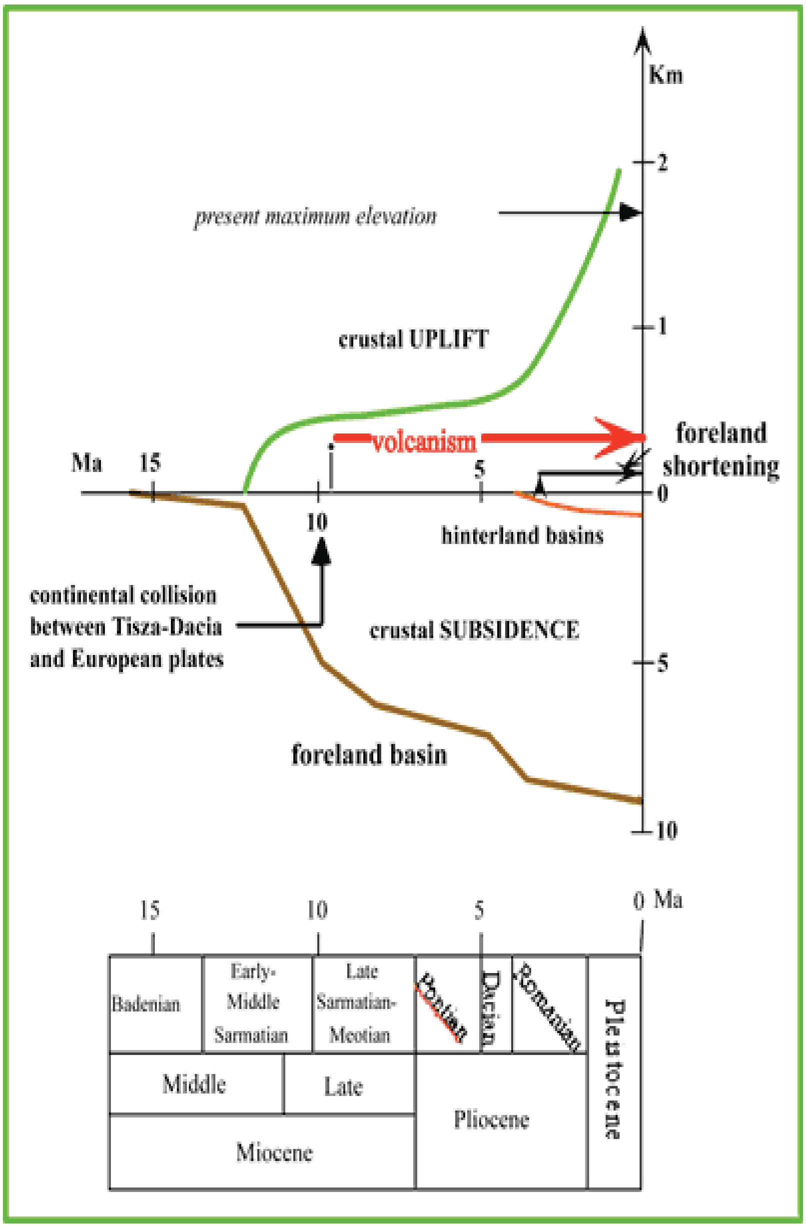
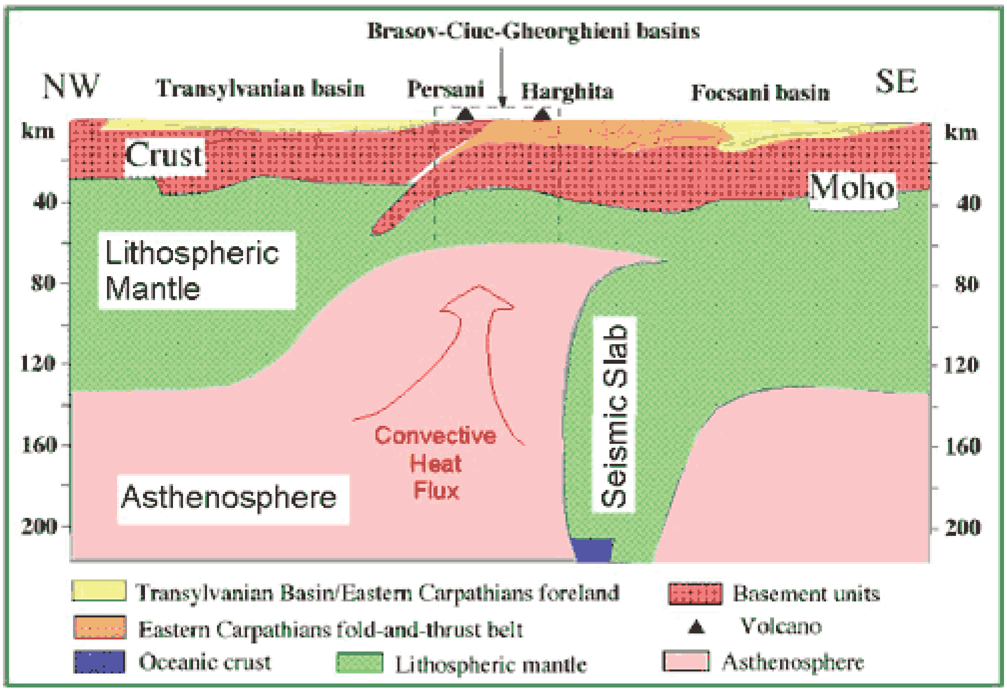


Figure 2: Timing of successive and coeval surface events in the southern Eastern Carpathians. The different curves represent the subsidence of Focsani foreland, the uplift of the Carpathian chain and the hinterland subsidence leading to the Brasov, Ciuc and Gheorghieni basin formation, while straight lines represent the age intervals of the Late Miocene-Quaternary volcanic activity and of shortening of the internal part of the foreland basin. (Click on figure to enlarge.)

In an effort to decipher this setting of magma generation, the spatial and temporal distribution of shallow and deep phenomena (Figure 2) were examined in order to establish the degree of their interdependence. Our model indicates that intra-mantle delamination of the subducting European plate is the principal cause of a succession of events (Figure 3). It caused upwelling of the hot asthenosphere below the thinned continental lithosphere of the Carpathians, inducing uplift of the lithosphere and internal decoupling at the Moho by isostatic and thermal effects.

Figure 3: Delamination model proposed for the Pliocene-recent evolution of the Eastern Carpathians (after Girbacea & Frisch, 1998, modified). This model suggests that, during the continental collision in Miocene times, break-off of the west-dipping subducting slab occurred at a depth of 70 km. Slab break-off propagated horizontally towards the east, inducing lithospheric delamination, counterclock-wise rotation of the delaminated lithospheric segment and movement of the Vrancea slab (seismically active due to ongoing pull of the oceanic lithosphere) into its present position. Location of Figure 4b is shown for a better understanding of the model. Click on figure for a larger version.



During this uplift, the crust deformed flexurally while the mantle deformed in a ductile way. This triggered decompressional partial melting of the uppermost mantle lithosphere (Figure 4). Flexural deformation of the crust induced transient fracturing, allowing for the rapid ascent of magmas to the surface, as well as reactivation of an older detachment horizon at the base of the Carpathian nappe stack. Above this, the Brasov, Ciuc and Gheorghieni hinterland basins formed by extension and gravity spreading (Figure 5). The rapid subsidence of the Focsani foreland basin (Figure 2) is controlled by the load exerted on the lithosphere by the delaminated mantle slab that is still attached to it (Figure 3).

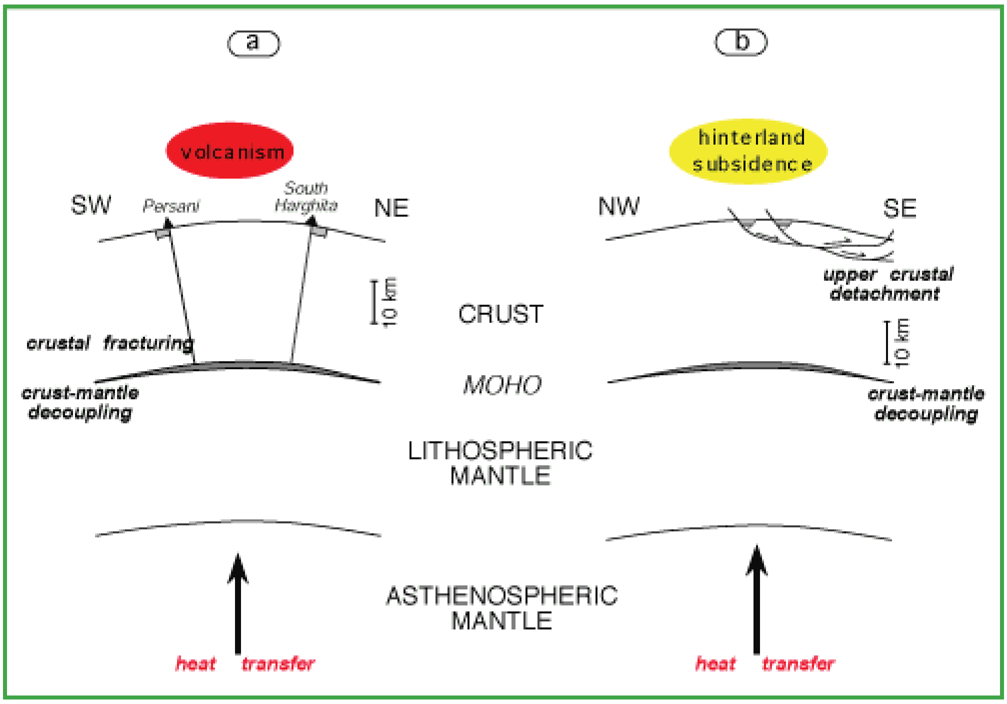
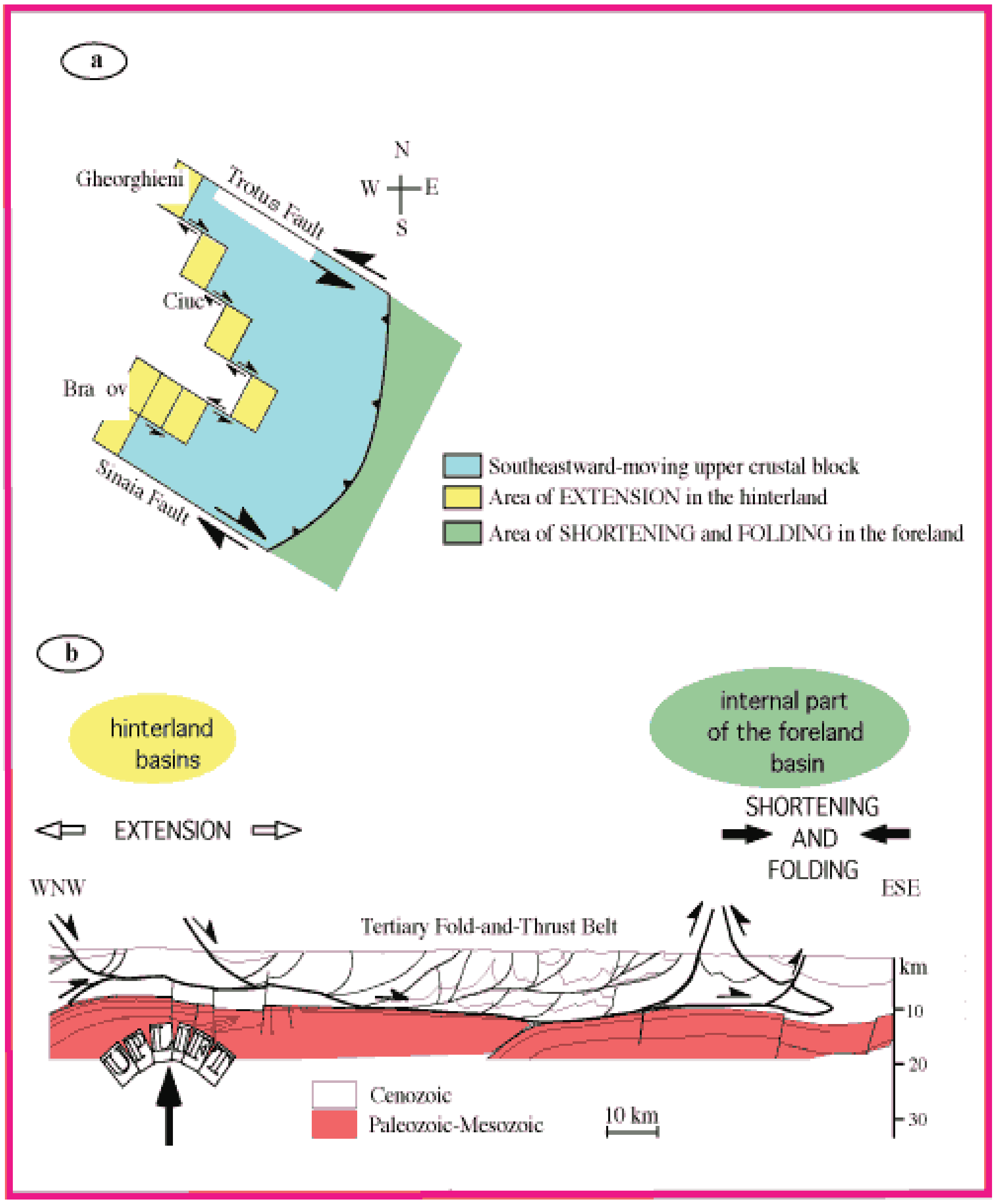


Figure 4: Geodynamic model explaining lithospheric uplift, volcanism and basin formation in the southern East Carpathians during the Late Miocene-Quaternary times. (a) SW-NE profile shows fracturing of the crust leading to volcanic eruptions; (b) NW-SE profile shows upper crustal detachment leading to hinterland basin formation by gravity speading. The succession of events is: 1- asthenospheric upwelling, itself induced by delamination of the lower part of the lithospheric mantle (see Figure 3); 2- density decrease and temperature increase of the overlying lithosphere leading to its uplift; 3- mantle-crust mechanical decoupling at the MOHO level due to the density gap between mantle and crust and their different rheological behaviour; crust bends and fractures, while mantle deforms in a ductile way, undergoes decompression and partial melting; 4a- injection under pressure of magmas throughout crustal fracturing and eruption at the surface; 4b- crustal extension and remobilization, in the upper crust, of an old detachment horizon above which hinterland basins form by gravity spreading towards the SE (see Figure 5).

Figure 5 (next page): a. Kinematic model of the Brasov-Gheorgieni basin formation and foreland folding. The uplift-induced southeastward motion of a crustal block between two strike-slip faults (Trotus and Sinaia) resulted in extension and basin formation in the hinterland, accommodated by coeval shortening in the foreland (see Figure 1 in Girbacea et al., 1998); b. the crustal motion has taken place above a detachment horizon within the fold-and-thrust belt (after Girbacea & Frisch, 1998 and Girbacea et al., 1998, modified).



In this model, crust-mantle decoupling, magma genesis, volcanism and local, near-surface hinterland extension are consequences of uplift induced by asthenospheric upwelling triggered by intra-mantle delamination.

This model suggests that delamination-induced decoupling began to be efficient 9.4 My ago at the northern end of the East-Carpathians, when the mantle slab dipped westwards. Subsequently, intra-mantle delamination migrated laterally, normal to the slab strike, and followed the arcuate shape (NW–>SE–>SW) of the Carpathians. Nowadays, whereas the mantle slab is still actively foundering below the Vrancea seismic zone to the SE of the most recently volcanic area (South Harghita - Persani), a significant southwestward shift of the delamination process can be discerned.

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