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Lithospheric gravitational instability beneath the Southeast Carpathians

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The Pannonian Basin, located in Eastern Central Europe, as part of the Alpine orogenic system, was formed as a result of extension of the crust and lithosphere between about 20 and 15 million years ago and is one of the fundamental elements in the structure of the European continent. The specific features of this basin, like the abnormal thinning of the mantle lithosphere relative to the crust, make it a key area for testing tectonic concepts. It has been suggested that the beginning of the extension in the Pannonian Basin was caused by the roll-back of subduction zones associated with convergence at the Carpathians. Present-day intermediate-depth seismicity underneath the southeastern part of the Carpathians has been attributed to the final stage of subduction, namely the slab break-off. In the northern part of the Carpathians the slab break-off is believed to have already taken place, since intermediate-depth seismicity is absent.

Located in the southeastern corner of the Carpathian arc, the Vrancea region is characterised by a particular zone of intermediate seismicity, representing the most intense seismic hazard in Europe. In typical geodynamic models for the Vrancea region a cold subducted slab underneath the Vrancea region sinks due to gravity. Buoyancy forces drive the sinking of the slab. Viscous forces however, resist the descent, producing an internal stress at intermediate depths. As a response to this stress, earthquakes occur in the downwelling lithosphere, which is stretched vertically. A successful geodynamical model for the present tectonic activity beneath Vrancea should also explain the formation of the adjacent Transylvanian Basin.

In this work, we explore an alternative model for this region based not on the idea of subduction of a plate, but rather on the idea of viscous flow of the lithospheric mantle permitting the development of local mantle downwelling beneath Vrancea. We present numerical experiments simulating the viscous downwelling of lithospheric mantle underneath the Vrancea region and its possible association with the development of the Transylvanian Basin. We use a parallelised 3D finite-element algorithm solving the basic equations of conservation of mass and momentum for a spatially varying viscous creeping flow, driven by boundary and internal buoyancy forces. The model enables a general 3D flow field to be computed for an arbitrary distribution of density and a stress-dependent viscous strength. Experiments that best describe the desired processes have been obtained by imposing an initial perturbation based on the m=1 Bessel function of the first type, namely a pair of localised positive and negative displacement anomalies. The motivation for using this particular perturbation is that it produces an asymmetric localised downwelling with an adjacent extensional basin. We present numerical results obtained for different wavelengths in order to characterise the wavelength-dependence of the growth-rate of the instability. We also examine the growth of the instability for varying crust:mantle viscosity ratios.