How seismicity relates to lithospheric heterogeneity in the Alps

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The Alps mountains and its forelands consist of a heterogeneous lithosphere, comprised of a multitude of tectonic blocks from different tectonic provinces with different thermo-physical properties. Patterns of seismicity distribution are also observed to vary significantly throughout the region. However, the relationship between seismicity and lithospheric heterogeneity has been often overlooked in previous studies. We present an overview of recent results that have attempted to address these questions through the use of integrated 3D modelling techniques, thereby including: (i) a gravity and seismic data constrained, 3D, density structural model of the lithosphere; (ii) a 3D thermal model constrained against available wellbore temperature data; and, (iii) a 3D rheological model of the long-term lithospheric strength and effective viscosities. Our models support the existence of a first-order correlation between the distribution of seismicity (laterally and with depth) and the strength of the lithosphere, with the former being clustered mainly within weaker domains. Beneath the Alps, observed upper-crustal level (i.e., unimodal) seismicity correlates with a weaker lithosphere where plate strength is controlled by the thick crustal root. Whereas in the southern foreland, weaker zones are found preferentially around the stronger Adriatic indenter while in the northern foreland they are located in the crust beneath the the Upper Rhine Graben (URG). We found that this correlation is primarily controlled by resolved thermal gradients and is a function of the tectonic inheritance setting (e.g., UGR), crustal architecture (e.g., thickness of sediments, upper and lower crust) and LAB depth. Sediment thickness and topographic effects controls the shallow thermal field (0 – 10 km) whereas the deeper thermal field is controlled by the thickness of felsic upper crust (higher radiogenic heat contribution), the mafic lower crust (less radiogenic heat contribution) and basal thermal boundary condition from LAB depth. Seismicity is bounded by specific isotherms, 450 °C in the crust and < 600 °C in the mantle, except in regions where slabs are imaged by seismic tomography models. This is in contrast to the recent proposition that convergence velocity is a first-order factor controlling seismicity in an orogen rather than its architecture. Fast convergence rates (e.g., Himalayas) have been related to the subduction of the cold crust to deeper crustal depths thereby leading to a deepening of the brittle domain and to a bimodal (i.e., upper and lower crust) seismicity character. In contrast, slow convergence (e.g., Alps) is thought to lead to a hotter ductile lower crust thus limiting brittle deformation within the upper crust. We therefore end our contribution by opening a discussion on the relative role of convergence rates and lithospheric heterogeneities, inherited and/or developed during orogenesis, in controlling the seismicity.
doing so we carry out a comparison between observed seismicity and lithospheric architecture in the other mountain ranges of the western Alpine-Himalayan collision zone where convergence velocities are of a similar order of magnitudes as Alps, i.e., the Betics, the Pyrenees and the Apennines but where seismicity is observed to occur both at upper and lower crustal levels.