Geophysical Research Abstracts
Vol. 20, EGU2018-9705, 2018
EGU General Assembly 2018

Controls on normal fault activity in the central Italian Apennines: Insights from thermo-mechanical modelling

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In the seismically active central part of the Italian Apennines, extensional faulting and devastating earthquakes occur within a narrow (<100 km wide) zone along the crest of the mountain range. While the underlying mechanism is still highly debated, strong evidence exists that enhanced elevations in this central area cannot be explained by thicker crust compared to adjacent parts of the Apennines. Instead active surface uplift and extensional faulting in this area over the last ca. 3 Myr appears to be related to the removal of mantle lithosphere. In particular, the width of the zone of extension and spatial and temporal variations in extensional strain rates appear to correlate systematically with the distribution of topographic elevation. We investigate factors controlling the evolution of faulting and topographic development in response to the removal of mantle lithosphere using a 2D thermo-mechanical model. Surface uplift in our model is generated dynamically by the progressive convective removal of dense mantle lithosphere (triggered by a small thermal anomaly) and replacement by hot less dense sub-lithospheric mantle leading to isostatic uplift. Faults (predefined weak fault zones), in turn, respond dynamically to both topographic uplift (gravitational effect) and rheological changes. In general, our model demonstrates a strong coupling between faulting and topography, with normal faults being only activated above a few hundred meters of elevation and the peak topography, in turn, being limited by fault activity. However, we also show that topography alone is not sufficient for activating faults and a small amount of far-field extension is required. More specifically, we observe in the model changes in the spatial pattern of fault slip rates over time and in the degree of strain localisation. We evaluate over what time scales these different developments occur and what the relative contributions are of faulting and regional uplift for topographic development. Overall, we constrain our model and evaluate our results using observational data from the central Apennines.