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Rapid cooling and exhumation of lower crust: insights from numerical modelling

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SE Asia roughly covers roughly 15% of the Earth's surface and represents one of the most tectonically active regions in the world, yet its tectonic evolution remains relatively poorly studied and constrained in comparison with other regions. Recent episodes of extension have been associated with sedimentary basin growth and phases of crustal melting, uplift and extremely rapid exhumation of young (<6 Ma) metamorphic complexes. This is recorded by seismic imagery of basins offshore Sulawesi and New Guinea as well as through new field studies of the onshore geology in these regions. A growing body of new geochronological and biostratigraphic data provides some control on the rates of processes. We use two-dimensional numerical models to investigate the evolution of the Palu Metamorphic Complex (PMC) in Sulawesi, Indonesia.

To constrain the extension rates and thermal structure needed to form the PMC, we perform a suit of numerical experiments with different permutations of extension rate and Moho temperature and we compare synthetic P-T and cooling paths with newly observed P-T and T-t paths. The numerical models show that high Moho temperatures are key to shaping the architecture of the stretched lithosphere: A) hot and weak lower crust fails to transmit stress and brittle deformation to deeper regions, resulting in a strong decoupling between crust and lithospheric mantle; B) the mode of deformation is dominated by the ductile flow and boudinage of lower crust, yielding the exhumation of one-to-several partially molten lower crustal bodies, including metamorphic core complexes; C) continental break-up is often inhibited by the ductile behaviour of the crust, and is only achieved after considerable cooling of the lithosphere.

Comparison of the numerical results with natural data confirms that extremely rapid exhumation of lower crustal bodies is related to very fast extension rates ($\sim$75 mm/yr) and Moho temperatures higher than those in more typically studied rift settings (e.g. Atlantic opening, East African Rift, Australia-Antarctica opening).