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Thermal elasticity promotes failure in the brittle-ductile crust

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Heating and cooling of rocks may lead to high internal stresses because contact stresses arise at the grain scale due to geometric mismatch between minerals with different and/or anisotropic thermal expansivities. Although thermally induced elastic stresses attracted large interest in rock mechanics, nuclear waste disposal, resource recovery and stimulation, they have never been considered as a candidate for the criticality of the continental crust on longer time scales. This is because it was assumed that thermal stresses are relaxed efficiently by temperature-activated creep in the ductile regime. However, viscous relaxation is a time-dependent process. Therefore, it may be possible that thermal-elastic stresses reach considerable magnitudes and lifetimes even in regions of the crust where ductile creep occurs. We tested this hypothesis with 1D and 2D grain-scale numerical experiments on granitic rock. The latter were calibrated with literature data from physical heating experiments on Westerly granite and with a time-lapse 3D high-resolution synchrotron X-ray tomography heating experiment. We found that deviatoric thermal-elastic stresses can easily reach magnitudes > 100 MPa and lifetimes from hundreds of thousands to millions of years in subsiding rock. Thus, thermally induced stresses may have a long-lasting impact on tectonics and the seismic cycle. They may bring the brittle-ductile crust close to criticality.