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Large-strain elastoplastic formulations for host-inclusion systems with applications to elasto-thermobarometry and geodynamic models

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Elastic thermobarometry has been at the forefront of research during the last decade. Using state-of-the-art spectroscopic and diffraction methods it has been possible to assess the residual elastic strain of mineral inclusions in an in-situ manner (Mazzucchelli et al., 2021; Zhong et al., 2019). The interpretation of residual stress/strain and its extrapolation to geological conditions requires mechanical models, that are based on continuum mechanics, which provide the range of pressure-temperature (P-T) conditions where host and inclusion are under homogeneous stress. This set of conditions may correspond to the entrapment conditions if the system is purely elastic. In the case of viscous/plastic relaxation of the host-inclusion system, the inferred P-T conditions represent apparent-entrapment conditions that could lie anywhere between the conditions of the true entrapment and the conditions of viscous/plastic relaxation (Moulas et al., 2020; Zhong et al., 2020). Thus, the interpretation and validity of elastic barometry strongly relies on the purely elastic behavior of the host-inclusion system.

The commonly employed elastic solutions assume a linear-elastic behavior and deal only with small-strain approximations. However, large values of residual stresses/strains may indicate that the range of decompression for such host-inclusion systems requires the incorporation of material/geometric non-linearity. In this work, we provide new numerical and analytical solutions for the non-linear, elasto-plastic behavior of host-inclusion systems. Our analytical solutions are based on new published models that describe the Neo-Hookean behavior of materials and reduce to the Murnaghan equation of state when the deformation is purely volumetric (Levin et al., 2021). We find that for the range of residual pressures that is commonly employed in barometric applications (<1GPa) the incorporation of geometric non-linearity does not influence the results significantly. Nevertheless, the incorporation of plasticity and the combined non-linear elastic and plastic behavior may lead to results that render elasto-thermobarometry inapplicable for very large compression/decompression ranges. Our results can be useful for benchmarking: a) models relevant to elasto-thermobarometry and b) geodynamic models that require the treatment of

large volumetric deformations during the exhumation from lithospheric/mantle depths.

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