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Pressure calculation in metamorphic systems and geodynamic models

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Pressure is one of the most important parameters to be defined in geological problems. In metamorphic systems pressure is usually calculated using two different approaches, each employing different sets of assumptions. One is based on petrologic phase equilibria, the other on thermo-mechanical considerations that predict stress and temperature evolution in time and space. These sets of assumptions are justified by the accuracy and applicability of the computed results. In this study we investigate the relationship between mean stress calculated by ensuring mechanical equilibria and thermodynamic pressure used to define the internal energy needed for chemical equilibria calculations. We discuss the meaning of thermodynamic pressure and its calculation for irreversible processes such as viscous deformation and heat conduction which are characterized by entropy production. Moreover, we demonstrate that the magnitude of mean stress evaluated at the incompressible limit during viscous deformation is approximately equal to the mean stress computed by a fully compressible formulation of mechanical equilibria provided that the tectonic processes operate in timescales 5 times longer than the characteristic Maxwell time (i.e the ratio of shear viscosity to bulk modulus). For typical lithospheric rocks this Maxwell time is smaller than one-hundred thousand years. Therefore, numerical simulations of long-term (>100 kyrs) geodynamic processes, which assume incompressible deformation provide accurate mean stress estimates even if elasticity is not taken into account.