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Grain-Scale Stresses and Metamorphic Phase Equilibria

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With the advance of analytical methods, it became apparent that thermodynamic equilibria in metamorphic rocks are mostly attained at small length scales. Chemical zoning in minerals and zones of mosaic equilibria testify that the equilibrium length scale commonly ranges from the μm to the cm scale. Despite the absence of complete chemical equilibration at small length scales, chemically zoned minerals and diffusion-controlled microstructures, in general, have proved useful for the rate estimation of geological processes. In addition, using the general framework of non-equilibrium thermodynamics, it has been demonstrated that chemical zonation in minerals can be the result of equilibrium under stress and pressure gradients. More recently, spectroscopic methods attest to the presence of stress and pressure variations from the μm to the cm scale. These variations can be of the order of several kbar and their measurement constitutes proof of the unrelaxed stress state of minerals at geological conditions. Consideration of host-inclusion systems shows that elastic models result in the development of differential stresses which are of the same magnitude as the residual pressure (mean stress) differences. Therefore, recent experiments and the successful application of elastic geobarometry both indicate that mechanically controlled rock micro-textures require the development of large differential stresses at the grain scale and can have a first order influence on metamorphic phase equilibria.