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Dramatic effects of stress on metamorphic reactions

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Temperature and pressure are primary controls on mineralogy in the Earth; calculations may predict mineralogy from temperature and pressure and vice versa. Such calculations assume that stress is isotropic despite the fact that differential stresses prevail in the Earth, resulting from large scale tectonics and/or differences between fluid and rock pressures in porous rocks. For more than 25 years I have explored how stress may interact with chemical effects through theory (Sheldon & Wheeler 2003, Wheeler 1987, 1992) and more recently experiments (Llana-Funez et al. 2012). New calculations (Wheeler submitted) show that differential stress can have very significant effects on thresholds for metamorphic reactions, depending on the grain-scale reaction pathways. A differential stress may, depending on the reaction pathway, have an effect equivalent to a pressure difference of the order of (assemblage volume)/(reaction volume change) times (differential stress). The multiplying factor is typically 10 or more. For example the onset of a garnet + clinopyroxene breakdown reaction may be offset by the equivalent of +500 MPa in pressure for a 50 MPa differential stress. The effect is equivalent to a temperature difference of the order of (assemblage volume)/(reaction entropy change) times (differential stress). For example the onset of muscovite + quartz breakdown may be offset by the equivalent of +130 degrees C for a 50 MPa differential stress. Much of the Earth is under differential stress, so the new calculations invite a reappraisal of metamorphic mineralogy and microstructure.

This is relevant for exploring possible deviations from lithostatic pressure in the Earth. Diagnosing the effect of pressure on mineralogy should be coupled to diagnosing the effects of differential stress – one effect may cloak the other but the scientific rewards for distinguishing them could be significant.

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