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If the rocks could speak: what compositional banding tells us about the distribution of stress in high grade metamorphic rocks

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Compositional banding produced by metamorphic differentiation has long been understood to result from mass transport by either dissolution or diffusion under the influence of a non-hydrostatic stress field. Explanations for how compositional differentiation initiates generally rely on high shear strains to orient pre-existing features or folding of a pre-existing foliation to form a pattern of fold noses and limbs that lead to preferential dissolution. I propose a new low-strain mechanism for the formation of compositional banding based on mass transport driven by local stress heterogeneities. Even in a nominally homogeneous rock, variations in the single crystal elastic properties of the constituent minerals, set up modulations in local stress states when the rock is placed under load. Using 2D finite element models, I show that these local variations in the differential stress can be $\sim$30% of the total load for a granitic rock. The modulations in stress form large scale patterns that are a function of the heterogeneity and statistical distribution of elastic and plastic properties across the population of grains and grain boundaries in the rock. The principle components of the stress tensor each have their own pattern that evolves with deformation. Initially, the principle compressive stress forms a strong pattern with a fabric parallel to compression. Once ductile deformation initiates, the least compressive stress evolves into a fabric perpendicular to compression, while the intensity of the compressive stress pattern diminishes. The pattern created by the least compressive stress is similar in scale (relative to the grain size) to typical gneissic banding. Mass transport of the more soluble minerals (quartz and feldspar) should tend to remove these minerals from areas experiencing high compressive stress and deposit them in areas experiencing less compressive stress, thus driving phase separation. Once feldspar rich bands are established, the comparatively high stiffness and plastic yield strength of feldspar will cause further localization of the least compressive stress into feldspar rich regions. Thus ensuring that once phase separation initiates, it will continue as long as the rock is experiencing a non-hydrostatic stress.