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Localization in Naturally Deformed Systems – the Default State?

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Based on the extensive literature on localized rock deformation, conventional wisdom would interpret it to be a special behaviour within an anticipated background of otherwise uniform deformation. The latter notwithstanding, the rock record is so rife with transient (cyclic), heterogeneous deformation, notably shear localization, as to characterize localization as the anticipated 'normal' behaviour. The corollary is that steady, homogeneous deformation is significantly less common, and if achieved must reflect some special set of conditions that are not representative of the general case. An issue central to natural deformation is then not the existance of localized strain, but rather how the extant deformation processes scale across tectonic phenomena and in turn organize to enable a coherent(?) descripion of Earth deformation.

Deformation is fundamentally quantized, discrete (diffusion, glide, crack propagation) and reliant on the defect state of rock-forming minerals. The strain energy distribution that drives thermo-mechanical responses is in the first instance established at the grain-scale where the non-linear interaction of defect-mediated micromechanical processes introduces heterogeneous behaviour described by various gradient theories, and evidenced by the defect microstructures of deformed rocks. Hence, the potential for non-uniform response is embedded within even quasi-uniform, monomineralic materials, seen, for example, in the spatially discrete evolution of dynamic recrystallization. What passes as homogeneous or uniform deformation at various scales is the aggregation of responses at some characteristic dimension at which heterogeneity is not registered or measured. Nevertheless, the aggregate response and associated normalized parameters (strain, strain rate) do not correspond to any condition actually experienced by the deforming material.

The more common types of macroscopic heterogeneity promoting localization comprise mechanically contrasting materials typical of most rocks. Such perturbations are of themselves only larger examples of variation in the fundamental defect distribution and response; that is the boundary conditions that induce heterogeneous response are reflections of the microphysical behaviour seen in aggregate as strain accommodating softening or stabilization processes such as grain size reduction and independent grain displacements. Additionally, cyclic interplay between inelastic rupture and subsequent plastic material softening resulting from the concomitant introduction of exogenous material in the form of igneous melts, deformation-induced melts and fluid precipitates (veins). This two-stage process determines the siting and temporary stabilization of the shear phenomena, and indicates that material hardening and non-associated flow over some characteristic time are precursors to any particular instability, with stabilization of localized shear correlated with system softening tied to redistribution of strain energy dissipation within what is effectively a reconstituted material.