Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SIT037-P09 Room: Convention Hall Time: May 26 17:15-18:45

Power-law rheology and microscopic heterogeneity

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Lots of composite materials, including rocks deformed under high temperature or undergoing semi-brittle failure by stress-enhanced corrosion reactions, show power law relation between bulk stress and strain rate. Mean field models to account for power law behaviour usually require a specific (often power-law) underlying distribution of local material properties, ideally conditioned on experimental and theoretical studies of microstructures such as chemical reaction rate theory on a uniform material or dislocation theory on high temperature creep. This mean field approach however ignores the collective dynamics or interaction of a population of microstructures, which bulk properties depend on especially at higher crack density. To examine the relative influence of material heterogeneity and crack-crack interactions, we develop a 2-dimensional spring-dashpot network with breaking bonds, and investigate the contribution of the distribution on microscopic relaxation times to a macroscopic rheology of power-law form. Specifically, we verify the possibility of non-power-law microscopic heterogeneity, e.g. a Gaussian distribution of relaxation times, leading to macroscopic power-law rheology.

Keywords: power-law, rheology, heterogeneity, relaxation time, creep, crack