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Role of inherited structures on the strength and strain rate of continental lithosphere

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Under the Wilson Cycle and Plate Tectonics paradigms, continents are divided between stable continental regions (SCR), which tend to remain un-deformed, and plate boundary zones (PBZ) that repeatedly accommodate deformation associated with opening and closing of tectonic plates. This long-term (> 1 Ma) perspective is reflected in short-term (< 100 a) deformation markers such as seismicity and GPS measurements, which highlight the first-order contrast in strain rates between SCR and PBZ. Despite this clear first-order view, significant debate remains regarding short- and long-term strength and deformation rates in intraplate weak zones (e.g., Rhine Graben, New Madrid seismic zone).

We propose to constrain first-order strength and strain rates using lithosphere rheological models, including new strain-weakening rheologies, driven by tectonic forces. We estimate average strain rates that satisfy near-failure equilibrium between net driving forces and lithosphere strength for cases that typify PBZ, cratons, and intraplate weak zones. Our model yields a range of strain rates that vary by up to six orders of magnitude between PBZ and cratons. In intraplate weak zones, structural and tectonic heritage results in significant weakening and yields strain rates compatible with GPS, seismicity, and geological markers. These results provide first-order constraints on long-term lithosphere strength and deformation rates. In particular, we explore upper and lower bounds of possible strain rates in intraplate weak zones, using a range of geotherm, rheology, and local stress conditions.