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The long-term strength of continental lithosphere: "jelly sandwich" or "crème brulée" ?

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The recent debate concerning the strength of continents has arisen, we believe, because of a mis-understanding about the manner that the lithosphere responds to loads at different time-scales. At the short seismic time scale loading, the entire lithosphere responds in brittle-elastic regime whereas at the long-time scales of ice or tectonic loading most of the strength comes from the ductile-elastic regime. Therefore, results from seismicity and flexure studies concerning, for example, the thickness of the elastic lithosphere (Te) and the viscosity of the asthenosphere will differ. Unfortunately, data from experimental rock mechanics cannot easily be interpolated to the temporal and spatial scales of geological processes (strain rates 10e-17 to 10e-13 1/s) without further parameterization. For oceanic lithosphere, the experimental Goetze-Evans brittle-elastic-ductile yield strength envelopes have been successfully validated using the observations of plate flexure. However, uncertainties in the results of flexure studies, together with their multi-layer rheology, has made it difficult to validate these data for continents. In one rheological model, dubbed "jelly sandwich" (JS), the strength mainly resides in the crust and mantle, while in another, dubbed "crème-brûlée"(CB), the mantle is weak and the strength is limited to the upper crust. We address these problems by reviewing rock mechanics data and by examining the physical plausibility of each rheological model. We next review Te estimates and their relationship to the seismogenic layer thickness (Ts). We then explore, by numerical thermo-mechanical modeling, the implications of a weak and strong mantle for structural styles. We show that, irrespective of the actual crustal strength, the CB model is unable to explain either the persistence of mountain ranges for long periods of time or the integrity of the lower plate in collisional systems. The models based on the JS rheology predict both Te and Ts fairly better than the models based on the CB rheology.