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Inferences of Integrated Lithospheric Strength from Plate-Scale Analyses of Deformation Observed in the Aegean-Anatolian Region and the Indian Ocean

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In the context of a comprehensive review of the rheology and strength of the lithosphere (Marine and Petroleum Geology, 2011, doi:10.1016/j.marpetgeo.2011.05.008), Evgene Burov described the difficulty of extrapolating rock deformation laws derived from laboratory experiments to the time and length scales that apply when the Earth's lithosphere is deformed. Not only does the extrapolation introduce a large uncertainty, but even the relative importance of different possible mechanisms of deformation may be uncertain. Even though lithospheric deformation has a strong conceptual and theoretical basis, it is therefore essential, as Burov argued, that deformation laws for the lithosphere must be calibrated by using observations of deformation that occurs on a lithospheric length scale and at geological strain rates. The influence of regionally varying factors like crustal thickness, geothermal gradient and tectonic environment may induce large variations in how rapidly the lithosphere may deform in response to an applied load, not least in the contrast from continent to ocean. Plates may be deformed by different loading mechanisms but, when deformation is distributed over a broad region, the strain-rate field may be approximately constant with depth and we may integrate the in-plane stress components across the thickness of the lithosphere to derive a depth-averaged constitutive law for the deformation. This approximation is the basis for the thin viscous sheet formulation of lithospheric deformation and, in combination with appropriate observations, it allows us to calibrate the integrated resistance to processes like regional extension or convergence. In this talk I will summarise what we learn about effective lithospheric rheology from two recent studies of the distribution and rates of diffuse deformation of the lithosphere in, firstly the Anatolian-Aegean region, and secondly the Central Indian Ocean. In the first case the distribution of deformation is consistent with a flow field that is driven by gradients of gravitational potential energy, and the rates of deformation are now well-constrained by extensive geodetic measurements. In the second case the rates are significantly smaller in magnitude, but the locations and mechanisms of broadly distributed intra-plate seismicity, together with structural interpretations of near-surface faulting allow us to constrain the distribution of a strain-rate field whose integrated effect is accurately defined by global tectonic models like MORVEL. Predictably, the resistance of Indian Ocean lithosphere to deformation is much greater than that of Anatolian lithosphere. We also infer a more strongly non-linear constitutive law for the oceanic example, but in both cases the magnitudes of depth-averaged stress difference appear significantly less than one would infer from the classic rheological profiles as summarized by Burov. These differences may indicate a significant role for pore fluids reducing stress-differences across faults in the crust and/or upper mantle, for grain-size reduction in shear zones, or for dislocation glide playing an important role in the deformation of the uppermost mantle.