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The rheology of the oceanic and continental lithosphere

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The rheology of the lithosphere controls the transmission of stress within plates and the deformation that occurs at their boundaries. In oceanic regions determination of earthquake depths and of the elastic thickness show that the upper part of the lithosphere, where the temperature is less than 600oC, behaves as a brittle solid. At higher temperatures stresses are relaxed over geological time scales by creep. This behaviour is that expected from laboratory experiments on dry peridotites. In contrast there is as yet no general agreement about the rheology of continental lithosphere, which has been the subject of a long-running controversy. The depths of continental intraplate earthquakes determined from P and S travel times are often as great as 100 km, and the elastic thickness determined from gravity and topography is commonly 100-150 km beneath shields. At such depths the temperature exceeds 1000oC, and in the laboratory stresses are relaxed at such temperatures within hours. Detailed examination of the waveforms of continental earthquakes can be used to determine their depths to an accuracy of about 5 km, and shows that the depths determined from travel times alone are sometimes in error by as much as 70 km. All depths so far determined from waveforms of continental earthquakes whose magnitude exceeds 5.5 are within the crust, and none occur where that estimated temperature exceeds 600oC. Determinations of the elastic thickness using the coherence method are affected by erosion, postglacial uplift and dynamic support, all of which cause the value estimated from the observations to exceed the true value. When proper account is taken of these effects estimates of the elastic thickness of continental lithosphere are everywhere less than the depth od the 600oC isotherm and are also less than the seismogenic thickness.