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Pore-fluid pressures and crustal strength

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The classic graph of crustal strength as a function of depth based on rock mechanics predicts a linearly increasing brittle strength above the brittle-plastic transition. This linear increase is a consequence not only of the pressure dependence of brittle strength but also an assumption that the depth-normalized pore-fluid pressure $\lambda = P_f/\bar{\rho}gz$ is constant, which is perhaps only plausible in the case of hydrostatic pore-fluid pressures ($\lambda_h = \rho_{H_2O}/\bar{\rho} \approx 0.4$). Much deep borehole stress data such as the German KTB borehole agrees with this assumption, showing the predicted linear increase in strength together with stress magnitudes that are consistent with hydrostatic pore-fluid pressures.

In contrast, observed pore-fluid pressures in deeper parts of deforming clastic sedimentary basins and active plate-boundary mountain belts are commonly in excess of hydrostatic, with λ not constant. These deforming sedimentary basins typically have pore-fluid pressures that are dominated by disequilibrium compaction, showing fully compacted sediments with hydrostatic fluid pressures at shallow depths until the fluid-retention depth z_{FRD} is reached, below which sediments are increasingly undercompacted and overpressured. For this disequilibrium-compaction mechanism, the fractional brittle weakening $(1-\lambda)$ below the fluid-retention depth is a simple function of depth $(1-\lambda) \approx (1-\lambda_h)[z_{FRD}/z]$, which directly leads to a predicted crustal-strength profile that is radically different from the classic hydrostatic profile. The brittle strength below the fluid-retention depth is predicted to be constant and approximately equal to the strength at the fluid-retention depth $\sigma_1 - \sigma_3 \approx 2(1-\lambda_h)K\bar{\rho}gz_{FRD}$, where the intrinsic pressure dependence is $K = sin\phi/(1 \pm sin\phi)$ in extension and compression. This prediction is illustrated with borehole fluid-pressure data from offshore China, Gulf of Alaska, Gulf of Mexico and western Taiwan.

The constant-strength prediction is tested with *in-situ* stress measurements in the actively extending Brazos region of offshore Texas, Gulf of Mexico. Borehole stresses are linearly increasing above the observed z_{FRD} and constant below it, as predicted. Furthermore, observations from western Taiwan show that z_{FRD} is fixed relative to the land surface during active uplift and erosion, therefore crustal strength should be approximately unchanged by exhumation except for cohesive effects. The full limits of the disequilibrium-compaction regime are not well know. However it is only as non-hydrostatic pore-fluid pressures decay that deformed sedimentary mountain belts are expected to show crustal strengths similar to the classic graph.