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Flexure and rheology of Pacific oceanic lithosphere

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The idea of a rigid lithosphere that supports loads through flexural isostasy was first postulated in the late 19th century. Since then, there has been much effort to investigate the spatial and temporal variation of the lithosphere's flexural rigidity, and to understand how these variations are linked to its rheology. We have used flexural modelling to first re-assess the variation in the rigidity of oceanic lithosphere with its age at the time of loading, and then to constrain mantle rheology by testing the predictions of laboratory-derived flow laws.

A broken elastic plate model was used to model trench-normal, ensemble-averaged profiles of satellite-derived gravity at the trench-outer rise system of circum-Pacific subduction zones, where an inverse procedure was used to find the best-fit T_e and loading conditions. The results show a first-order increase in T_e with plate age, which is best fit by the depth to the $400 \pm 35\,^{\circ}$C plate-cooling isotherm. Fits to the observed gravity are significantly improved by an elastic plate that weakens landward of the outer rise, which suggests that bending-induced plate weakening is a ubiquitous feature of circum-Pacific subduction zones.

Two methods were used to constrain mantle rheology. In the first, the T_e derived by modelling flexural observations was compared to the T_e predicted by laboratory-derived yield strength envelopes. In the second, flexural observations were modelled using elastic-plastic plates with laboratory-derived, depth-dependent yield strength. The results show that flow laws for low-temperature plasticity of dry olivine provide a good fit to the observations at circum-Pacific subduction zones, but are much too strong to fit observations of flexure in the Hawaiian Islands region. We suggest that this discrepancy can be explained by differences in the timescale of loading combined with moderate thermal rejuvenation of the Hawaiian lithosphere.