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An integration to optimally constrain the thermal structure of oceanic lithosphere

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The evolution through time of the oceanic lithosphere is a substantial, incompletely resolved geodynamical problem. Consensus remains elusive regarding its thermal structure, physical properties, and the best model through which to unify observational constraints. We robustly re-evaluate all three of these by i) simultaneously fitting heat flow, bathymetry, and temperatures derived from a shear velocity model of the upper mantle, ii) using the three main thermal models (half-space, plate and Chablis) and iii) analysing five depth–age curves, wherein contrasting techniques were used to exclude anomalous features from seafloor depths. The thermal models are updated to all include a temperature-dependent heat capacity, a temperature- and pressure-dependent thermal conductivity and an initial condition of adiabatic decompression including melting. The half-space model, which lets the lithosphere thicken indefinitely, cannot accurately fit the subsidence curves and requires mantle potential temperatures, T_m, that are too high. On the other hand, the models including a mechanism of basal heat supply are able to simultaneously explain all observations within two standard errors, with best-fitting parameters robust to the choice of the filtered bathymetry curve. For the plate model, which imposes a constant temperature at a fixed depth, T_m varies within 1380–1390°C, the equilibrium plate thickness a within 106–110 km, and the bulk thermal expansivity $\bar{\alpha}$ within $2.95–3.20 \cdot 10^{-5}$ K^{-1}. For the Chablis model, which prescribes a fixed heat flow at the base of a thickening lithosphere, the best-fitting values are $T_m = 1320–1380$°C, $a = 176–268$ km, $\bar{\alpha} = 3.05–3.60 \cdot 10^{-5}$ K^{-1}. Driven by more accurate ocean depths, the plate model provides better joint-fittings to the observations; however, it requires values of $\bar{\alpha}$ lower than experimentally measured, which can be explained by a reduction of the apparent expansivity due to elastic rigidity of the upper lithosphere. The Chablis model better fits the data when $\bar{\alpha}$ is set close to or above the experimental values. Whilst statistically consistent within two standard errors, a tendency toward incompatibility between observed depth–age curves and seismically-derived temperatures is revealed with new clarity, as the latter do not exhibit a clear steady state whereas the former flatten: further work is needed to identify the origin of this apparent discrepancy. This work opens the way to investigations fully independent from particular solutions of the heat equation.