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The Effect of Horizontal Thermal Contraction on Oceanic Intraplate Deformation: Examples for the Pacific

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Young oceanic lithosphere is not rigid. Instead it contracts horizontally owing to thermal cooling. Because depth-averaged cooling rate, and thus depth-averaged linear contraction rate, is inversely proportional to the age of the lithosphere, contraction rates range from 0.01 to 1 nanostrain/yr for 170 and 1.7 Myr-old lithosphere, respectively. These rates are small, but are one to three orders of magnitude greater than the average oceanic intraplate strain rate inferred from seismic moment release. Predicted displacement rates are different for directions parallel and normal to mid-ocean ridges, depend strongly on lithospheric age, and are dependent on the actual ridge-transform geometry. Ridge-parallel velocities can be substantial (several mm/yr) when integrated over long distances along young lithosphere for hypothetical plate geometries having no offsets of isochrons.

We will use the method of Haines and Holt to model the self-consistent horizontal strain rate field that best fits the expected strain rates, and calculate the corresponding velocity field relative to the oldest part of the considered plate. For a simple case of a large rectangular plate bounded by a 1300-km-long ridge on one side, we find ridge-parallel velocities for 1.7 Myr-old lithosphere to be 1.3 mm/yr over the length of ridge, as expected. For more realistic cases with stepped and crenellated transform offsets, velocities could locally near the ridge reach several mm/yr, but the total ridge-parallel rate is significantly less. When we model the velocity field for the Pacific plate using observed ridge-transform geometries and ages from Müller et al. (2008), we find northwest-directed velocities of up to 0.8 mm/yr near the southern East Pacific rise and southwest-directed velocities of similar magnitudes near Baja California. Through additional analysis of GPS data on the Pacific plate, we will show whether this deformation can be observed and how it would alter the definition of Pacific plate motion.

Although small, the effect of horizontal thermal contraction needs to be quantified and considered when estimating plate motions from sea floor data. In particular, the contraction will cause systematic biases in transform fault orientations. Furthermore, the effect can add up to a few mm/yr when considering certain plate circuits, and could partly, if not entirely, explain the non-closure of some circuits in global plate motion models such as NUVEL-1A and MORVEL.