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Using latest Miocene changes in Pacific plate motion to analyze plate boundary forces

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Studies have documented many rapid changes along the Pacific-North American, Pacific-Antarctic and Pacific-Australian plate boundaries in latest Miocene to earliest Pliocene time, like the opening of the Gulf of California and the uplift of the Southern Alps of New Zealand.
These events are consistent with a sudden clockwise rotation of Pacific plate motion at 6 Ma. We hypothesize that this change in plate motion was initiated by cessation of subduction along the northern Melanesian arc due to the collision between the arc and the Ontong Java plateau.
The southwest Pacific is a tectonically highly active region with a convoluted history of plate boundary evolution which is not easy to constrain. The approach we take is therefore powerful and novel since it uses global geological observations to constrain a local tectonic event.
There is ample evidence that the collision between the arc and the oceanic plateau led to a slab-breakoff and subsequent subduction polarity reversal along the northern Melanesian arc. The consequence is a change in plate boundary forces in this region which we aim to quantify with a modeling approach.

To support the hypothesis we use a finite element thin shell code to model the global plate tectonic setting before and after the change in motion, using multibeam observations of fracture zone trends along the Pacific-Antarctic plate boundary to determine the angular velocity vector that describes the change in Pacific plate motion at 6 Ma. We impose pre- and post-6 Ma plate velocities and calculate the necessary plate driving torques.
The strength of our model is that we look at different settings with a small time interval in between. Therefore, we can assume that the drag forces from the mantle are constant. Also forces due to lateral changes in gravitational potential (e.g., ridge push) do not change drastically if the platewide topography is relatively unchanged. Thus, a change in slab-related forces is expected to be responsible for this change in plate motion. However, the amount and direction of this change need to be identified with the model.

Our model results show that the change in motion is caused by a clockwise rotation of the slab-related plate driving force. The change of the slab-related force from a post-6 Ma to a pre-6 Ma setting is approximately perpendicular to the strike of the arc, points towards the Australian plate (with a bearing of S2.89°W) and has a force per unit length of approximately 4×10^{12} N/m. This is in the range of currently accepted values for subduction zones. Since there have been no other relevant changes at subduction zones along the Pacific plate boundary during the latest Miocene, we relate this change in slab-related force to the former southward-dipping Pacific plate slab along the northern Melanesian arc system which is now detached.
The results strongly support our hypothesis that the change in plate motion was initiated by cessation of subduction along the northern Melanesian arc.

We can use these quantitative insights to better understand plate behavior in general. We can analyze for example the implications of our results for the origin of the bend in the Hawaiian Emperor seamount chain: The relatively large change of forces needed to induce a rotation of plate motion of 5° - 15° at 6 Ma leads to the conclusion that the bend cannot be only due to a rotation of Pacific plate motion, but is at least partly due to a moving Hawaiian hotspot.